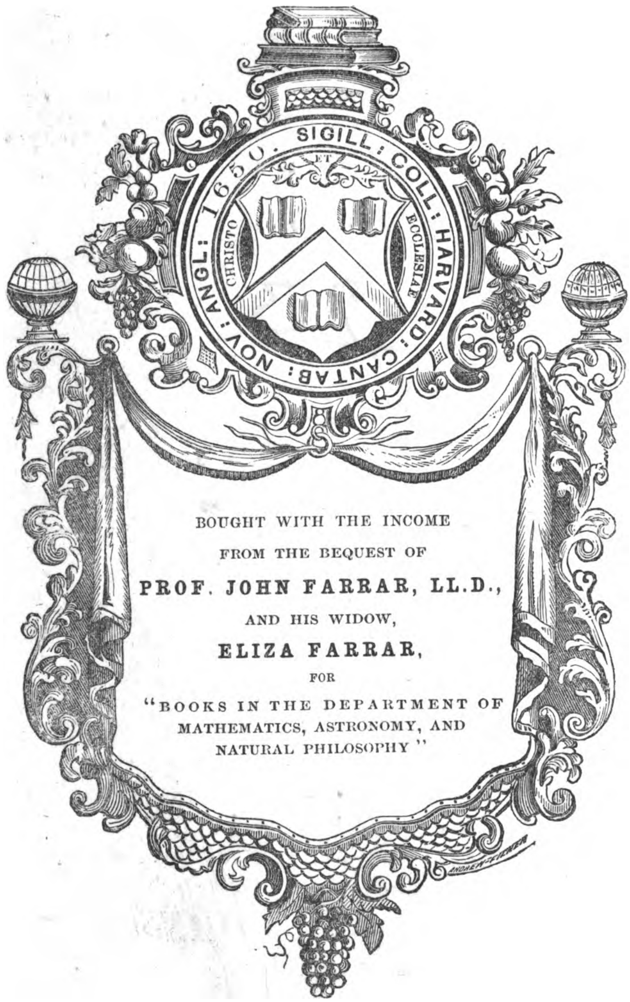
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THE CURVE OF COMPRESSION IN THE STEAM ENGINE.

By J. C. HOADLEY.

Whoever has had occasion to examine carefully the curves of indicator diagrams, has probably found that none of the formulæ given by Rankine and others, for curves of expansion, represent, with even tolerable accuracy, the compression curves actually drawn by the instrument.

Clearance (including "waste room") being accurately known, the indicator in good order, the scale of the spring correct, and the diagram satisfactory; the curve of compression will always be found steeper than the curve of expansion; higher at the upper end, and lower at the lower end, than any normal or theoretical curve ever employed to represent expansion curves. There are, as it seems to me, obvious reasons for this. Steam, during its expansion in the steam engine, performs work, and the heat energy converted into kinetic energy, must result in condensation of steam, and in a consequent depression of the curve at its lower end. This condensation is generally counteracted, often far exceeded, in the case of engines with unjacketed cylinders, especially when running at low rotatory speed, by re-evaporation of water condensed during admission. Professor Rankine's adiabatic curve, or curve of no heat transmission, is adapted to the hypoth-

esis that just enough heat will be supplied by the jacket to prevent the condensation of vapor; so that while doing work by expansion against a moving resistance, the steam in the cylinder will be constantly maintained in the condition of "dry, saturated steam." This hypothesis is well sustained by facts obtained from steam-jacketed cylinders running with a rotatory velocity of 125 to 300 revolutions per minute. At the lower speed, 250 reciprocations per minute, or over 4 per second, the actual curve is very little indeed above the adiabatic, at its lower end. With the higher speed, 600 reciprocations per minute, 10 per second, the adiabatic curve represents the actual curve with great accuracy.

But in curves of compression, the case is quite different. Work is here converted into heat; and some water present in the steam must be evaporated, adding to the tension. Heat transmitted from the steam jacket tends to accentuate, not to disguise this effect. I had long desired a formula which should fairly represent this curve; which would answer for compression curves, as well as the "adiabatic" does for curves of expansion; and having obtained from one of my engines, at the Centennial Exhibition, some diagrams of unusual delicacy and accuracy, with very early closure of the exhaust, and pretty high boiler pressure (145 above the atmosphere), I attempted the solution of the question, by a method of which I here propose to give a detailed account. The diagram taken from the end of the cylinder nearest to the crank was first tried, and gave results so encouraging that I proceeded to apply the same method to the diagram taken from the end of the cylinder farthest from the crank, using still greater care in every step of the work. This diagram is to be preferred to that taken at the other end, as it is exempt from the disturbing influence of the piston-rod, no inconsiderable surface condenser, being exposed half the time to the air of the engine room, not to dwell on possible leakage at the stuffing box. This diagram was taken Aug. 8, 1876, preparatory to a public trial made a few weeks later, by the Judges of Group XX and experts appointed by the Centennial Commission.

The engine, a semi-portable, or "entire engine," had 14·5 inches diameter of cylinder and 20 inches stroke. The speed, as then regulated, was 123 revolutions per minute. The clearances, as then adjusted, were: end nearest to the crank, ·0794; at the end farthest from

G

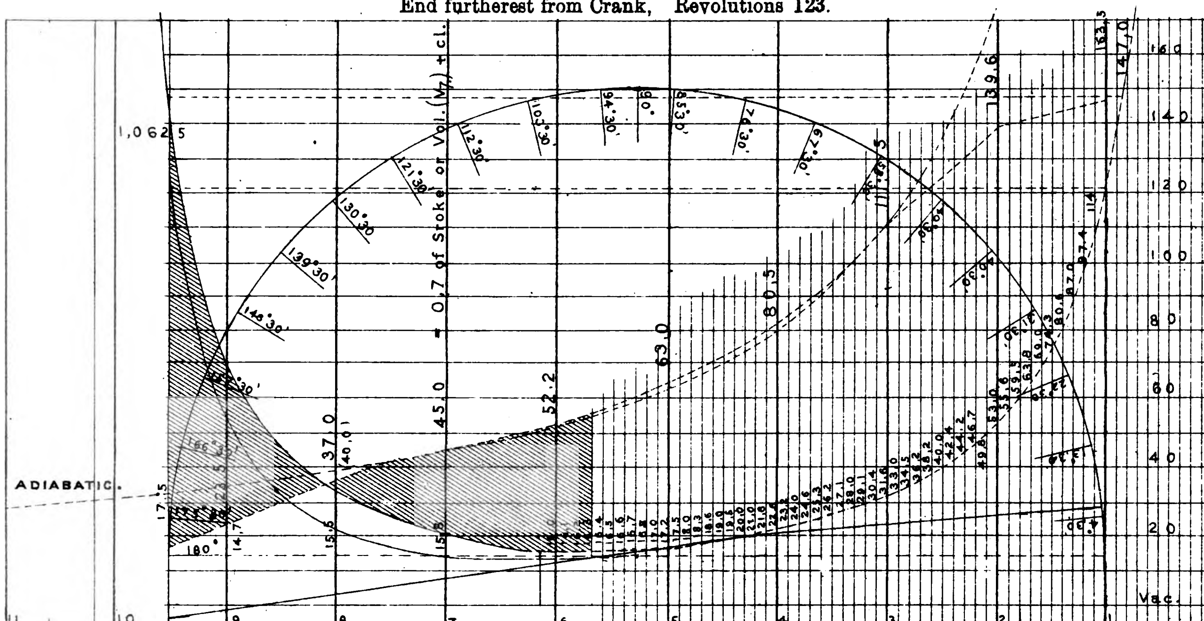
DIAGRAM TAKEN AUGUST 8TH, 1876.

Portable Engine No. 1270, the J. C. HOADLY Co., $14\frac{1}{2}'' \times 20''$, tested at Centennial Exhibition, September 7th, 1876.

Boiler Pressure, 1451 14.7=159.7. Scale of Indicator Spring, 56 lb. per inch.

$L=\frac{19.6}{4}=4.9$ in. Expansion $=\frac{1}{0.2519}=3.97$. Virtual Cut-off=.2519. Clearance .1161.

End furtherest from Crank, Revolutions 123.



crank, ·1161 of volume swept through by the piston, of course taking into account the volume of piston rod.

The boiler pressure, as before stated, was 145 lbs. by steam gauge. The friction brake on the balance wheel was set at about 72·7 H P., and the effective power developed in the cylinder was about 80 H. P. The cut-off was entirely under the control of the governor; and, with a boiler pressure so high as 145 lbs., took place early. Subsequent adjustment, before the trial, equalized a little more nearly both clearance and cut-off at the two ends of the cylinder. When the diagrams under consideration were taken, virtual cut-off (total fill, including clearance, divided by total volume, including clearance) was, at the end nearest to crank, at ·1949 of stroke; at the end farthest from crank, ·2811. The ratios of expansion, the reciprocals of these numbers, were therefore $\frac{1}{\cdot 1949} = 5{\cdot}1308$ and $\frac{1}{\cdot 2811} = 3{\cdot}5574$, giving a mean expansion of 4·34. The length on the line of volumes equal to clearance (·1161 of stroke), was laid off from the dead centre, and divided into 10 parts; and this $\frac{1}{10}$ clearance (·0116 of stroke) was made the unit of division for the whole length of the compression urve; these divisions are laid on the diagram, and are fairly accurate.

After division, and laying down the line of vacuum, or zero of absolute pressure, 14·7 lbs. below the atmosphere line, the next step was to measure the pressures, or the heights of the ordinates, from No. 11, the first ordinate beyond the dead centre (beginning at the end of clearance), to No. 60, which falls at ·4195 of return stroke = ·5805 before the end of the stroke; and is ·5937 — ·4195 = ·1742 short of the closure of exhaust. The measured ordinates, therefore, embrace the whole of the compression curve, and considerably more at the lower end; and the first measurement at No. 11 (V_{11}) is rather outside of the limit of accuracy, on account of the obliquity of the angle of intersection; and also on account of the proximity of the dead centre, and of the point of valve-opening.[1]

[1] The "lead" of the valve, or its actual width of opening at dead centre, was invariably 1-16 inch. The angle of lead and the throw of the eccentric were under the control of the governor; the angular advance varying between 30° and 90°, and the throw of the eccentric between 5 and 2·5 inches. The point of return stroke, therefore, at which the valve opened, was variable; at the earliest, a very little farther from dead centre than V_{11}; at the latest, extremely close to dead centre, (V_{10}). In the case under consideration, the valve was not opened until after the piston on its return stroke had passed V_{11}.

The method of investigation is by the differences of the logarithms representing the volumes, the serial numbers 1, 2, 3, etc., to 60; and the differences of the logarithms of the corresponding ordinates; the several differences of the latter series being divided by the corresponding differences of the former series, giving their ratio, or the Nat. tang. of the angle at the base. The mean of these ratios, care being taken to embrace none extending beyond the probable limits of curve, gives the exponent sought, for the whole curve, provided the curve can be fairly represented by the formula $P \propto \overline{V^n}$, to use Prof. Rankine's notation, or $\frac{V^n}{V_1^n} = \frac{P}{P_1}$, or P proportional to $\frac{1}{V^n}$.

This method is carried out numerically in the Table A, for 33 pairs of differences, $\overline{11, 12}$ to $\overline{45, 46}$, giving a mean value of $n = 1{\cdot}247$.

Again taking the differences $\overline{12 \text{ to } 45}$, we obtain $n = 1{\cdot}2366 = \frac{5}{4}$ nearly.

The same method is worked out graphically on diagram B, in which the abscissæ represent the logarithms of the numbers, $1 = 0{\cdot}0000$, $2 = 0{\cdot}3010$, etc., to $60, = 1{\cdot}7782$; and the ordinates, the logarithms of the corresponding pressures as measured on the original diagram. *A B* gives the entire series, and is a graphical representation of Table A. The first measurement to be fully trusted, is as V_{12}. The number 12 being highly divisable, we can easily obtain other tests of the same construction, on other parts of the scale. At *a b*, for instance, we divide by 6, and so take every second ordinate; at *a′ b′*, dividing by 4, we take every third ordinate; at *a″ b″*, dividing by 3, we use every fourth ordinate; at *a‴ b‴*, dividing by 2, we use every sixth ordinate; and finally, taking the whole volume of the clearance as our unit, we get at *a⁗ b⁗*, only 5 of our measured ordinates, namely, V_{12}, V_{24}, V_{36}, V_{48} and V_{60}. These six curves are all mutually confirmatory. All show the same feature at the lower end, beyond the curve of compression, and all give the same angle, the natural tangent of which is the exponent sought. There is a little oscillation, best seen at *A B*, and *a b*, caused by the inertia of the reciprocating parts of the indicator; which first resist motion, then move a little too far, and then oscillate with diminishing amplitude.

The mean of all the ratios, $\overline{12, 13}$, to $\overline{44, 45}$, Table A, is $1{\cdot}247$. The ratio of the differences for the extremes of the series, $\overline{12, 45}$, is $1{\cdot}2366$. The difference between these two ratios is slight—only 4 *per cent.*, and they are extremely near to $1{\cdot}25 = \frac{5}{4}$, or the fifth power of the

Table A.

Portable Engine, No. 1270, the J. C. Hoadley Co., 14½″ × 20″, tested at the Centennial Exhibition, Sept. 7th, 1876. Diagram G, taken Aug. 8th, 1876. 145 lbs. gauge pressure in boiler. Compression curve. Cl. = ·1161, divided into 10 parts. The 10th ordinate is at dead centre.

Nos. Volumes. V.	B. Logs. of Ordinates.	C. Difference of Logs.	D. Measured Absolute Pressures. P.	E. Logs. of Pressures.	F. Difference of Logs.	Ratios. $\frac{F}{C}$	
10	1·0000						Dead Centre, ≐ V_{10}
11	1·0414	414	114·	2·0569			
12	1·0792	378	97·4	1·9886	683	1·807	
13	1·1139	347	87·	1·9395	491	1·415	
14	1·1461	322	80·6	1·9063	332	1·031	
15	1·1761	300	74·3	1·8710	353	1·175	
16	1·2041	280	69·	1·8388	322	1·150	
17	1·2304	263	63·8	1·8048	340	1·293	
18	1·2553	249	59·5	1·7745	303	1·213	
19	1·2788	235	55·6	1·7451	294	1·251	
20	1·3010	222	53·	1·7243	208	·937	
21	1·3222	212	49·8	1·6972	271	1·278	
22	1·3424	202	46·7	1·6693	279	1·381	
23	1·3617	193	44·2	1·6454	239	1·238	
24	1·3802	185	42·4	1·6274	180	·973	
25	1·3979	177	40·	1·6021	253	1·429	
26	1·4150	171	38·2	1·5821	200	1·170	
27	1·4314	164	36·2	1·5587	234	1·427	
28	1·4472	158	34·5	1·5378	209	1·323	
29	1·4624	152	33·	1·5185	193	1·269	
30	1·4771	147	31·6	1·4997	188	1·279	
31	1·4914	143	30·4	1·4829	168	1·175	
32	1·5052	138	29·1	1·4639	190	1·377	
33	1·5185	133	28·	1·4472	167	1·256	
34	1·5315	130	27·1	1·4330	142	1·092	
35	1·5441	126	26·2	1·4183	147	1·167	
36	1·5563	122	25·3	1·4031	152	1·246	
37	1·5682	119	24·6	1·3909	122	1·025	
38	1·5798	116	24·	1·3802	107	·914	
39	1·5911	113	23·2	1·3655	147	1·301	
40	1·6021	110	22·6	1·3541	114	1·036	
41	1·6128	107	21·8	1·3385	156	1·458	
42	1·6232	104	21·	1·3222	163	1·567	
43	1·6335	103	20·	1·3010	212	2·058	
44	1·6435	100	19·5	1·2900	110	1·100	
45	1·6532	97	19·	1·2788	112	1·154	41·158 ÷ (83 − 45 − 12) = 1·247.
46	1·6628	96	18·6	1·2695	93	·968	
47	1·6721	93	18·3	1·2625	70	·753	
48	1·6812	91	18·	1·2553	72	·791	
49	1·6902	90	17·5	1·2430	123	1·367	
50	1·6990	88	17·2	1·2355	75	·852	
51	1·7076	86	17·	1·2304	51	·593	
52	1·7160	84	16·8	1·2253	51	·607	
53	1·7243	83	16·7	1·2227	26	·313	
54	1·7324	81	16·6	1·2201	26	·321	
55	1·7404	80	16·5	1·2175	26	·325	
56	1·7482	78	16·4	1·2148	27	·346	
57	1·7559	77	16·3	1·2122	26	·338	
58	1·7634	75	16·2	1·2095	27	·360	
59	1·7709	75	16·1	1·2068	27	·360	
60	1·7782	73	16·0	1·2041	27	·370	
		71					

12 = 1·0792, and 1·9886
45 = 1·6532, and 1·2788

·5740 ·7098

and ·7098 ÷ ·5740 = 1·2366.

Exponent of $V = n = 1·25 = \frac{5}{4}$.

fourth root, which is a very convenient number to use, even without logarithms, as the fourth root is easily obtained by extracting the square root twice, and this square root of the square root, multiplied by the original number, gives the fifth power sought.

I subjoin an example of the method employed for computing points in the curves from the exponent, $n = 1{\cdot}2366$.

V_{12}. Log. of 12 = 1·0791812, and its log. = 0·0330944
" " (1·2366 = exponent, n, of V) = 0·0922292

0·1253236

The natural number corresponding to this logarithm is itself the log. of $V_{12}^{1.2366} =$ 1·3345153

$P_{12} = 97{\cdot}4$, and its log. = 1·9885590

Constant log. = (log. of $V_{12}^{1.2366} \times P_{12}$) = 3·3230743

V_{13}. Log. of 13 = 1·1139434, its log. = 0·0468636
" " 1·2366 0·0922292

0·1390928

Nat. number corresponding to this log. = log. of $V_{13}^{1.2366}$ to be subtracted from constant log. = 1·3775038

$P_{13} = 88{\cdot}22$, its log. = 1·9455705

In the following table the curve is computed, from V_{12} to V_{45}, by the exponent 1·2366, starting with $V_{30} = 31{\cdot}6$, and using only 4 places of decimals in the logarithms; the ordinates being carried out only to one place of decimals. The pressure measured at V_{30} on the diagram, = 31·6, is taken as a starting point because it is midway of the length of the curve, and so situated that all the conditions are favorable to the accuracy of the measurement, confirmed, as it is, by the measurements on both sides of it.

For the constant logarithm, we have:

V_{30}. Log. of 30 = 1·4771213, and its log. = 0·1694162
" " 1·2366, 0·0922292

" " $V_{30}^{1.2366}$ = 1·8266080 = Nat. No. of log. = 0·2616454

$P_{30} = 31{\cdot}6$; its log. = 1·4996871

log. $V_{30}^{1.2366} \times P_{30} = 3{\cdot}3262951$ = Constant log.

PORTABLE ENGINE No. 1270.
THE J. C. H CO., $14\frac{1}{2}'' \times 20''$.
TESTED AT THE CENTENNIAL EXHIBITION, SEPT. 7, 1876.
Diagram G—end furthest from Crank.
COMPRESSION CURVES.
J. C. H.

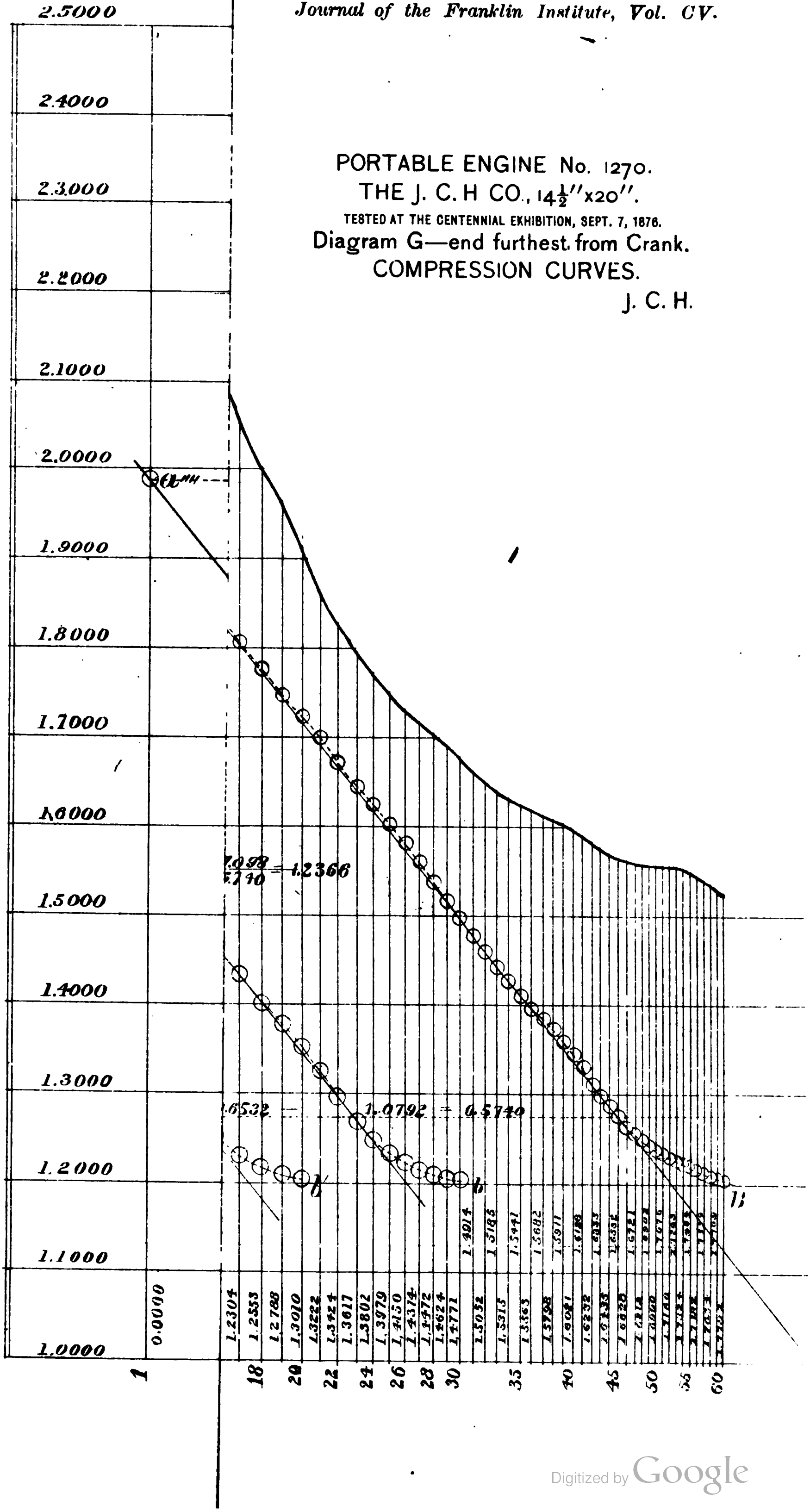


Table C.

Calculation of Compression Curve by the Formula $P \propto \frac{1}{V^{1.2366}}$, Starting at $P_{30} = 31·6$.

A Numbers of Ordinates. Volumes. *V.*	B Logs. of Volumes. Logs.	C Logs. of the Logs. B. Logs.	D Logs. C + a constant log. of 1·2366 = 0·0922. Logs.	E Nat. Numbers of D = Logs. of $V^{1.2366}$ Logs.	F Logs. E subtracted from the constant Log. of $V_{30}^{1.2366} \times P_{30} = 3·3263$. Logs.	G Nat. Numbers of F, computed Ordinates. Pressures.—Lbs. per square in.	H Measured Ordinates. Pressures.—Lbs. per square in.	I Differences. Lbs. per square inch.
12	1·0792	0·0331	0·1253	1·3345	1·9918	98·1	97·4	+ ·7
13	1·1139	0·0468	0·1390	1·3772	1·9491	88·9	87·	+ 1·9
14	1·1461	0·0592	0·1514	1·4171	1·9092	81·1	80·6	+ ·5
15	1·1761	0·0704	0·1626	1·4541	1·8722	74·5	74·3	+ ·2
16	1·2041	0·0807	0·1729	1·4890	1·8373	68·7	69·	— ·3
17	1·2304	0·0900	0·1822	1·5213	1·8050	63·8	63·8	0
18	1·2553	0·0987	0·1909	1·5520	1·7743	59·5	59·5	0
19	1·2788	0·1068	0·1990	1·5813	1·7450	55·6	55·6	0
20	1·3010	0·1143	0·2065	1·6088	1·7175	52·2	53·	— ·8
21	1·3222	0·1213	0·2135	1·6349	1·6914	49·1	49·8	— ·7
22	1·3424	0·1279	0·2201	1·6600	1·6663	46·4	46·7	— ·3
23	1·3617	0·1341	0·2263	1·6838	1·6425	43·9	44·2	— ·3
24	1·3802	0·1399	0·2321	1·7065	1·6198	41·7	42·4	— ·7
25	1·3979	0·1455	0·2377	1·7286	1·5977	39·6	40·	— ·4
26	1·4150	0·1508	0·2430	1·7500	1·5763	37·7	38·2	— ·5
27	1·4314	0·1558	0·2480	1·7701	1·5562	36·0	36·2	— ·2
28	1·4472	0·1605	0·2527	1·7894	1·5369	34·4	34·5	— ·1
29	1·4624	0·1651	0·2573	1·8084	1·5179	33·0	33·	0
30	1·4771	0·1694	0·2616	1·8264	1·4999	31·6	31·6	0
31	1·4914	0·1736	0·2658	1·8442	1·4821	30·3	30·4	— ·1
32	1·5052	0·1776	0·2698	1·8612	1·4651	29·2	29·1	+ ·1
33	1·5185	0·1814	0·2736	1·8776	1·4487	28·1	28·	+ ·1
34	1·5315	0·1851	0·2773	1·8937	1·4326	27·1	27·1	0
35	1·5441	0·1887	0·2809	1·9094	1·4169	26·1	26·2	— ·1
36	1·5563	0·1921	0·2843	1·9244	1·4019	25·2	25·3	— ·1
37	1·5682	0·1954	0·2876	1·9391	1·3872	24·4	24·6	— ·2
38	1·5798	0·1986	0·2908	1·9534	1·3729	23·6	24·	— ·4
39	1·5911	0·2017	0·2939	1·9674	1·3589	22·9	23·2	— ·3
40	1·6021	0·2047	0·2969	1·9811	1·3452	22·1	22·6	— ·5
41	1·6128	0·2076	0·2998	1·9943	1·3320	21·4	21·8	— ·4
42	1·6232	0·2104	0·3026	2·0072	1·3191	20·9	21·	— ·1
43	1·6335	0·2131	0·3053	2·0198	1·3065	20·3	20·	+ ·3
44	1·6435	0·2158	0·3080	2·0324	1·2939	19·7	19·5	+ ·2
45	1·6532	0·2183	0·3105	2·0441	1·2822	19·2	19·	+ ·2
Algebraic sum of differences								2·3

Divided among 34 numbers, $\frac{2·3}{34} = ·07$, or less than one-tenth of a pound per sq. in.

It will be observed that 19 of the computed ordinates fall below the corresponding measured ordinates; 9 fall above, and in 8 cases, including the starting point, P_{30}, the computed and measured ordinates are equal.

The aggregate of the minus differences is 6·5, which, divided by 19, gives about $\frac{1}{3}$ pound as a mean (·342). The aggregate of the plus differences is 4·2, which, divided by 9, gives less than $\frac{1}{2}$ pound (·467) as the mean. The algebraic sum of the differences is 2·3, which, divided by 34, gives the mean of the whole less than ·1 pound (·07).[1]

Let us now compute the same curve by the formula $P \propto \frac{1}{V^{\frac{5}{4}}}$, that is, substituting for the value of the exponent, $n = 1·2366$, the simpler number $n = \frac{5}{4}$, starting as before at V_{30}, and with the same measured pressure, $P_{30} = 31·6$.

Having at hand a list of modified logarithms from 1 to 100, in which each logarithm is increased by $\frac{1}{4}$ of itself, I find:

$$\begin{array}{ll} \text{Log. } (30)^{\frac{5}{4}} = & 1·8464016 \\ \text{Log. } P_{30} = 31·6, & \underline{1·4996871} \\ \text{Log. } V_{30}^{\frac{5}{4}} \times (P_{30} = 31·6), & 3·3460887, \text{ Constant log.} \end{array}$$

A comparison of the differences in column H, Table D, with the corresponding differences in column I, Table C, will show that the exponent $n = \frac{5}{4}$ represents the actual curve almost, but not quite as accurately as the exponent $n = 1·2366$. The differences between these two computed curves are seen in column G, Table D. The principal difference is at the upper end, and if the 7 numbers, $\overline{12}, \overline{18}$, are omitted, the differences for the remainder of the curve will balance each other. The approximate exponent $\frac{5}{4}$ gives a curve a little steeper than the more accurate exponent 1·2366; a little higher at the upper end and a little lower at the lower end. Both approximate with reasonable accuracy to the measured curve. As curves of compression rarely (save in the locomotive) begin so early in the stroke, or extend

[1] The scale of the indicator spring is 56 lbs. to the inch. Therefore:

$$\begin{array}{l} ·342 \text{ lbs.} = ·0061 \text{ in.} = \frac{1}{164} \text{ in.} \\ ·467 \text{ lbs.} = ·0083 \text{ in.} = \frac{1}{120} \text{ in.} \\ ·07 \text{ lbs.} = ·0013 \text{ in.} = \frac{1}{787} \text{ in.} \end{array}$$

TABLE D.

CALCULATION OF COMPRESSION CURVE BY THE FORMULA $P \propto \frac{1}{V^{\frac{5}{4}}}$, STARTING AT $P_{30} = 31{\cdot}6$; AND COMPARISON OF THIS CURVE WITH THE CURVE COMPUTED IN TABLE C, AND WITH THE MEASURED CURVE.

Volumes. V.	Logs. of $V^{\frac{5}{4}}$. Logs.	Logs. of $V^{\frac{5}{4}}$ subtracted from constant 3·3461.	Ordinates By $n=\frac{5}{4}$.	By $n=1{\cdot}2366$.	By Measurement.	Differences. D, E.	D, F.
A	B	C	D	E	F	G	H
12	1·3490	1·9971	99·3	98·1	97·4	+ 1·2	+ 1·9
13	1·3924	1·9537	89·9	88·9	87·	+ 1·0	+ 2·9
14	1·4327	1·9134	81·9	81·1	80·6	+ ·8	+ 1·3
15	1·4701	1·8760	75·2	74·5	74·3	+ ·7	+ ·9
16	1·5052	1·8409	69·3	68·7	69·	+ ·6	+ ·3
17	1·5381	1·8080	64·3	63·8	63·8	+ ·5	+ ·5
18	1·5691	1·7770	59·9	59·5	59·5	+ ·4	+ ·4
19	1·5984	1·7477	55·9	55·6	55·6	+ ·3	+ ·3
20	1·6263	1·7198	52·5	52·2	53·	+ ·3	— ·5
21	1·6528	1·6933	49·4	49·1	49·8	+ ·3	— ·4
22	1·6780	1·6681	46·6	46·4	46·7	+ ·2	— ·1
23	1·7022	1·6439	44·0	43·9	44·2	+ ·1	— ·2
24	1·7253	1·6208	41·8	41·7	42·4	+ ·1	— ·6
25	1·7474	1·5987	39·7	39·6	40·	+ ·1	— ·3
26	1·7687	1·5774	37·8	37·7	38·2	+ ·1	— ·4
27	1·7892	1·5569	36·0	36·0	36·2	0	— ·2
28	1·8089	1·5372	34·5	34·4	34·5	+ ·1	0
29	1·8280	1·5181	32·9	33·0	33·	— ·1	— ·1
30	1·8464	1·4997	31·6	31·6	31·6	0	0
31	1·8642	1·4819	30·3	30·3	30·4	0	— ·1
32	1·8814	1·4647	29·2	29·2	29·1	0	+ ·1
33	1·8981	1·4480	28·1	28·1	28·	0	+ ·1
34	1·9143	1·4318	27·0	27·1	27·1	— ·1	— ·1
35	1·9301	1·4160	26·1	26·1	26·2	0	— ·1
36	1·9454	1·4007	25·2	25·2	25·3	0	— ·1
37	1·9603	1·3858	24·3	24·4	24·6	— ·1	— ·3
38	1·9747	1·3714	23·5	23·6	24·	— ·1	— ·5
39	1·9888	1·3573	22·8	22·9	23·2	— ·1	— ·4
40	2·0026	1·3435	22·1	22·1	22·6	0	— ·5
41	2·0160	1·3301	21·4	21·4	21·8	0	— ·4
42	2·0291	1·3170	20·7	20·9	21·	— ·2	— ·3
43	2·0418	1·3043	20·2	20·3	20·	— ·1	+ ·2
44	2·0548	1·2918	19·6	19·7	19·5	— ·1	+ ·1
45	2·0665	1·2796	19·0	19·2	19·	— ·2	0
Algebraic sums of differences						+ 5·7	+ 3·4
Mean differences						+ ·17	+ ·1

NOTE.—The greatest difference + 2·9 lbs. = ·0518 in., say $\frac{1}{20}$ in. The mean ·17 lb. = ·003 = $\frac{1}{330}$ in. The mean, ·1 lb. = ·0018 = $\frac{1}{560}$ in.

to so great a height, as in the diagram here under consideration, the formula $P \propto \frac{1}{V^{\frac{5}{4}}}$ will generally be found sufficiently accurate for cards from steam-jacketed cylinders, with not less than 120 revolutions per minute, 4 reciprocations per second.

But convenient as this formula is, and closely as it represents compression curves in engines similar to the one from which this diagram was taken, it will always be found more satisfactory to deduce a special formula for each engine, or each class of engines, from accurate diagrams, carefully divided (accurate knowledge of the clearance being a necessity), and the object of this paper will be best accomplished if it shall be found of any assistance to the engineering profession in the investigation of such curves. I will only add the obvious remark, that the method here set forth is equally applicable to expansion curves, and will in all cases give the best possible representation of any given curve which can be obtained by any formula for a curve of the hyperboloid order.

ON THE RELATION OF MOISTURE IN AIR TO HEALTH AND COMFORT.[1]

By Robt. Briggs, C.E., Cor. Mem. Am. Inst. of Architects, etc.

It may be accepted that the most pleasant condition of the air, in our portion of the globe, will be found to exist on a fair day in early summer, when the temperature ranges from 62° to 68° Fahr., and the moisture present in the air is from 85 to 80 per cent. of saturation. On a day like this, no thought of the weather is taken, and the passage of the conversational compliment of a "fine day" becomes a needless reminder, to be accepted without discussion or thought. Admitting this proposition as a fact, it is the purpose of this paper to show that in our climate this summer condition of relative heat and moisture is not desirable, or even attainable, at other seasons, in the ventilating or heating of occupied places. And in presenting this view to the American Society of Architects, I do so with a full knowledge that it does not accord with the opinion of most American

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[1] Paper read before the Am. Institute of Architects, at Boston, Oct. 18th, 1877.

writers on the subject of ventilation, who have derived their information and their arguments mainly from the study of English and French books, and have only endeavored to reconcile the data found in these to American wants and practice. Even Wyman, who is by far the most original as an observer, as well as the most thorough as the collator of information from all sources, hardly makes the distinctive effect of our low temperature, combined with a comparatively lower dew point, sufficiently evident.

Except one investigates the relation of moisture to temperature of air in the two countries, it is impossible to reconcile our facts with the statement of good foreign authorities,[1] that 56° is comfortable, and 62° is warm in living rooms in mid-winter; while the American shivers with cold at 70°, and is not overwarmed at 76° in the apartments of his own dwelling, although clad in the thickest of underclothing. Investigation, however, shows that the deprivation of heat from the person is more due to evaporation from the lungs or throat, and from the skin, than from heat otherwise dispersed; whether carried off by the breath, imparted to the air, or radiated to surrounding objects. And further investigation will show that the hygrometric state of the air has so much effect in inducing or retarding evaporation, as to make 56° Fahr. in the West and South of England, in Ireland and in Normandy, sensibly as warm as 80° in Canada or Minnesota at the same season. A brief statement of the difference of climatic condition of England and of America may show why we cannot import English theories of ventilation and heating, and apply them at once, without modification, to American residences. The English climate affords nearly eight months in every year, when the thermometer ranges between 40° and 60° in the shade, with a dew point so high, that it is a pleasure to exercise in the invigorating air; one month of 60° to 80°; and three months from 25° to 50°; there

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[1] The comfortable warmth of air indoors is given by various authorities, as follows: Peclet, "Traité de la Chaleur," gives 15° Cent., 59° Fahr. Morin, "Etudes sur la Ventilation," for nurseries, schools, etc., 59°; hospitals, 61° to 64°; theatres, assembly halls, etc., 66° to 68°! Tredgold, "Principles of Warming and Ventilating, etc.," 56° to 62°. Reed, "Illustrations of the Theory and Practice of Ventilation," 65°. Hood, "Treatise on Warming Buildings, etc.," inferentially 55° to 58°. Parkes, "Manual of Military Hygiene," 48° to 70° (this author has encountered the difficulty of naming a fixed temperature, and avoids the issue). Box, "Practical Treatise on Heat," 62°. Others might be quoted, but these are amongst the best authorities on Heating and Ventilation.

being no term, except a part of the one month of heat reaching to 80°, when any person cannot, with suitable clothing, enjoy the open air. While in America there is scarcely one month (or 30 days) out of the year, having an average temperature of 50° to 75° (which temperatures, from the difference of dew point, correspond sensibly with 40° to 60° in England); and there are three months of 75° to 90°; three months of 30° to 50°; and five months of excessive variation of temperature of from 0° to 50°. During the three hot months, and also during most of the five cold, open air exercise to those whose avocations are within doors, is, if not impossible, at least very uncomfortable, however clad or covered. Anyone, who is called upon to endure the fervid summer heat, or who can habituate himself to the inclemencies of our arctic winter, will not suffer great discomfort, nor experience much injury to his health therefrom; but the weak and tender—the merchant from his counting house, the student from his closet, the workman from the shop, the women and children of the house—cannot acquire the endurance or the habit, and must shelter and protect themselves.

This preamble to the subject has been intended to impress the fact that its consideration must be on its own merits, and not through the light thrown upon it by general writers, that its investigation shall be original from physiological considerations, and not based upon authorities.

§ Comfort, if not existence, depends upon a constant loss of heat from the person. The internal natural warmth of the body is very nearly 100° Fahr., regardless of the heat of the external air, and the personal comfort which proceeds from the temperature and humid condition of the air, proceeds from the cooling effect which must then occur with constancy and regularity, and yet not so fast as to produce the sensation of cold. The origin of the natural heat is well established. There is inhaled by each adult in comparatively still life, each 3 to 4 seconds, from 30 to 40 cubic inches of air, at such temperature as may exist at the place, with extreme differences of temperature ranging from —40° to + 140° Fahr., and with extremely variable proportions of humidity, from the point of saturation on the one hand to that of nearly an anhydrous air on the other. The practical extremes in our country are from little below zero to about 100°, accompanied also with great variation of humid condition. A portion of the oxygen of the inhaled air is consumed in the system; and the exhala-

tion, which follows each inhalation, emits about 4 per cent. of carbonic acid, and $1\frac{1}{2}$ per cent. of vapor of water. Two or three grains of carbon are consumed in the system each minute, giving out $3\frac{3}{4}$ to $5\frac{3}{4}$ units of heat; the unit of heat being the equivalent to a pound of water heated 1° Fahr. It is the dispersion of this heat which establishes the sensation of comfort. Modern theory has established the convertibility of heat to work or power, and some portion of the heat evolved by the air of respiration will have been converted into labor or effort, but far the greatest portion will have been utilized in preserving the temperature of the body from the losses by evaporation of moisture, by conduction and by radiation. One portion of the loss is readily estimated. The breath is inhaled at whatever temperature and humidity may subsist at the place, but is exhaled at all times at 90° (when the temperature of the air is not above that degree), and it is saturated with moisture at that temperature. If it is supposed that the temperature of the external air is 62°, and the dew point 54° (= 65 per cent. humidity), from 0·35 to 0·56 unit of heat will have been expended in evaporation of moisture in the lungs and throat, and 0·10 to 0·17 unit of heat in imparting heat to the exhaled air each minute. About $3\frac{1}{2}$ times as much heat will have been expended in supplying the moisture, as in heating the air. The loss of other portions of heat cannot be as definitely estimated. It is evident that it must mainly be dispersed from the skin, and it is pretty certain that a large, if not much the larger, portion must pass off in insensible perspiration, which will be greatly affected by the condition of humidity of the surrounding air. Here clothing becomes an important element. We protect ourselves against the inclemency of winter, or the heat of summer, by coverings more or less non-conducting or non-radiating, leaving but a small portion of the person unprotected by direct exposure. An almost instinctive preference is given by all people, of all times, and at all places, for porous clothing; even the skins which clothe the inhabitants of the coldest regions, although quite impervious to moisture and to currents of air, are very open for the passage of vapor of water, or of diffused gases. Evaporation, and consequent cooling of the skin, takes place in great measure, or is influenced by the relative vacuum which the quantity of vapor present in the air establishes. The transfer of vapor is then one of diffusion, and follows the law of diffusion of gaseous bodies. A partially anhydrous air, external to the clothing, is a partial vacuum

to the vapor of 90°, existing in ducts of perspiration, and this vapor rushes towards the vacuity without encountering the resistance of any circulation, and meets no considerable obstacle in the porous coats and overcoats. It is in this way possible to explain why, in mid-winter, with the room from 65° to 70°, heavy underclothing is not only endurable, but necessary. The overcoat may be removed on entering the well warmed house, but no discomfort follows from the retention of warm garments, that, with a summer condition of air of the same temperature, would be oppressive. We sleep in rooms, which, if not warmed to the full heat of our living rooms, have yet the "temperate" point of indication by the thermometer, and in this case enjoy a pile of bed clothing, which would be suffocating in weather of the same natural temperature. The American requirement of comfortable drawing room clothing is strikingly different from that of England. The ladies' English drawing room dress is an impossibility in America. Even the rigorous laws of fashion fail to conform themselves in this case, and yet our American drawing rooms are *hotter* than the English ones.

What proportion of the heat generated by formation of carbonic acid to be dispersed from the body after taking out what is abstracted by exhalation and by labor of work or animal life, is expended in vaporization of water, is of course doubtful. Some authorities give 2 to $2\frac{1}{2}$ lbs. of water to be evaporated, each day, by insensible perspiration. These quantities would give (nearly) 2000 to 2500 units, or $1\frac{1}{2}$ to $1\frac{3}{4}$ units of heat per minute, and, together with the quantity of heat dispersed in breathing (on the previous supposition), account for one-half of the heat produced; leaving one-half the heat to be dispersed in work, life, or conduction to air, or radiation to other bodies. These authorities quoted are, however, English, and it is uncertain what quantity of moisture is evaporated from the skin in heated rooms in mid-winter in our climate.

It is probable that in still air, with the person in repose, the transfer of heat, either from the person or the clothing, whether from radiation or from conduction, is nearly equal; but in any current of air or movement of the individual, the effect of conduction will much exceed that from radiation. It should be remembered, however, that a current of air always exists about any person. The comfortable temperature of the air being lower than that of the person, there is established, by the heat imparted to the air by the person, an ascen-

sional current surrounding and enveloping him, sufficiently defined to be measurable by a delicate anemometer, which is effective in augmenting considerably the convection of heat over what would occur in entirely still air. Assuming any comfortable temperature for air between 60° to 80°, the exhalations of breath by virtue of extra temperature and the presence of vapor to saturation, notwithstanding the addition of some carbonic acid gas of greater density than that of the air, are still so much lighter than the air as to ascend at once after the directional impulse from the mouth or nostrils will have expended itself, which, when the act of breathing has its normal force, and is not made violent by running or exertion, occurs within two feet.

In all cases the sensibility to loss of heat, whether from the breath as exhaled moisture or heated air, or from the person as evaporation from the skin, or as conduction to air, or by radiation to cooler objects, this sensibility, I say, varies in the several regards with different persons, with different races or nations, and above all, with the habits from business pursuits or occupations, or the customs or fashions of the place of living; any of which causes may and will have established a regime in each individual, and their comfort will depend upon conformity thereto. The occupation, business or habits of individuals as regards their labor or exercise, both when at labor or exercise, or when at rest, cause much discrepancy in demands for heat. In the coldest and dryest day, few young persons can fail to warm themselves to the point of comfort in skating—many of the trades demand special temperatures for the workmen, some requiring special temperature and moisture condition of the air for the work—to which temperature and condition the workmen must conform.

There are three means provided for the healthful dispersion of animal heat into the atmosphere; the first is radiation to surrounding colder objects; the second, conduction to the atmosphere, which, for comfort, must be sensibly cooler than the body, and the third is evaporation from the moist surfaces of the lungs, throat, and the roots of the pores of the skin. The first of these means, to the clothed person at least, is comparatively ineffective, while the relative quantities of heat which may be eliminated in any given time or locality, by the last two, will probably be found nearly equal in an atmosphere of about 70° temperature and 65 to 70 per cent. of humidity. In all cases of *excess* of animal heat, the animal, and mankind as an animal,

find relief in evaporation of water secreted in the system, showing that vaporization is the ultimate means of dispersion of heat.

Even the races of animals exhibit diversity of natural methods of dispersing the surplus animal heat. Thus the dog obtains relief through the breathing functions, and extends the surface of evaporation by exposure of the tongue, while the horse breaks out into profuse perspiration of the skin.

The relation of what is indicated by the sense of cold or warm to definite temperature with varied proportions of humidity, may be examined at this stage of the argument. Considering a nearly saturated atmosphere, it will be found that its effects differ with the temperature altogether. Such an atmosphere at from 35° to 50° is found to be intolerably chilly, and although evaporation may be checked, and this source of loss of heat be removed, yet the conductive and radiating value of the vapor in the air is now elevated enormously. The cooled surface of the cuticle absorbs the natural heat of the skin, and represses the evaporation of secretions almost entirely. An actual transfer of heat from the skin to the vapor in contact with the surface occurs, the superheated vapor no longer rushes away from the skin, in search of that vacuum, which is the accompaniment of a usually low dew point, but merely transfers its heat to the next particle of cold vapor, which is packed in convenient juxtaposition to receive it; or else an actual movement of the heated vapor effects a circulation or current which brings a new cold particle to receive a new increment of heat. In an atmosphere of this nature, the exhaled breath, and the exhaust steam from the workshops, evolve a cloud of apparent vapor, which must condense in cooling as the air absorbs its heat, for the saturation of the air forbids its absorption as an invisible gas. A Scotch mist of 36° (which is only a supersaturated air with vapor in excess at a slightly higher temperature than the air) penetrates clothing, and reaches every part of the person with distressing frigidity.

Passing upwards in the scale of temperatures from 50° to 65°, the point of equilibrium of cooling action by conduction or radiation of vapor in the air, with supply of heat from checked evaporation of the skin or lungs for attainment of comfort, seems to be reached. Perhaps the most healthful, or at least most stimulating, atmosphere for human breathing is found within these limits, when of natural and continued existence, so that within and without the doors the same

condition exists, and the regime of the bodily system is not disturbed from hour to hour.] This, if not the ruling climatric condition of English life, at least is the presumed theoretic standard of English writers. Mental or physical exercise, alike, either separately or in conjunction, are supported by this condition of the atmosphere to an extent which no inhabitant of the frigid north, or enervating south, can imagine.

Some curious physiological phenomena accompany this atmospheric condition, one of which is the possibility of use of stimulants of the milder nature (wine and malt liquors), in quantities which would be immoderate in our climate. With the comparative cessation of cutaneous evaporation, it seems as if action of the alcoholic ingredient of the liquors were much changed and rendered more stimulating and less intoxicating.

From 65° to 80° a saturated atmosphere is sultry and oppressive. The surplussage of heat cannot be removed by conduction, and the natural effort of the system is to induce evaporation. The least physical effort produces, in the healthy person, abundant sensible perspiration, and the cooling effect of evaporation of a heated surface of water into a cooler air is the natural remedy. The lassitude and enervation of this step in the scale is eminently unfavorable to mental as well as to physical labor.

Above 80° a saturated air becomes burdensome; it is even questionable if life could be prolonged in a saturated air of 90° to 100°, and it is certain that at some point, not much above 100°, suffocation would ensue when any exertion should raise the animal heat above its normal degree. The deaths in the Black Hole of Calcutta were the result of excess of moisture, rather than of heat, or want of air *per se*. There are travelers' tales of regions on the Red Sea, and near the mouth of the Persian Gulf, where men cannot breathe in summer for the heat combined with moisture.

In the same way that the effect of a nearly saturated atmosphere has been examined, that of a very dry one may be investigated. To the sense of feeling all air may be said to be dry below 35°. The small amount of vapor present, and possible to exist as vapor below this point, reduces the conductivity so that the chilliness, to a great degree, disappears, even in a saturated air. Yet even here the cold producing effect of a high dew point is felt in a wind, so that from 15° to 35° the N. E. wind of our Eastern states is a very raw one. But,

on the other hand, with a dry air from 40° below zero to the freezing point, the immediate sensation of cold by the active man, well clad with porous clothing, is yet endurable, and with habit becomes almost pleasant. Still these temperatures are not those suited to civilized life, either physical or mental. As has been before noticed, we have in the Northern states about five months of the year, when the temperature ranges from 0° to 50°, and consequently when our civilized avocations demand artificial heating. The winter climate of the Eastern, Northern and Middle states, is one of great vicissitudes, with extremes, both of temperature and of hygrometric conditions following each other rapidly. In the Northwestern states, it seems that a somewhat greater uniformity of temperature, and a much more uniform hygrometry, exist during the winter months, but in the Middle Western states the irregularities appear to be as frequent as in the Eastern states. Except that the length of the winter season is a little cut short, and the excessive cold is a little alleviated in the southern portion of the belt of country I have designated, much the same phenomena of climate exist all through the states north of the 40th parallel of latitude. Throughout this territory it has become recognized that the minimum temperature of comfort for heated and ventilated rooms can be stated at 70°, with an admitted, and generally supposed inexplicable, if not unreasonable, demand, for 75° to 78° in some localities and at some times.

§ Ventilation means a supply of fresh air to the occupants of a house, workshop or meeting room of any kind; and as a final result, the quantity of such supply needed to attain the desired purity is from 40 to 60 cubic feet of air for each person each minute, where the contents of the rooms can be considered as furnishing a portion of the supply when occupancy is only for a part of the time. Much of the air may not be supplied through the heating apparatus. In cold weather, when the levity of the heated air within a building, compared with the colder air on the outside, produces a great pressure of outer air near the ground, the leakage of air at cracks of the door and window frames, at the top of the building, and its replacement by colder air through similar apertures at the bottom, furnish a much larger volume of air than is generally supposed. The strong winds also seek such leaks. Some permeability of walls, even of boards well painted, is available for the diffusion of vapor and of

gases in a measure. So that the proper quantity of air to be supplied by an apparatus, becomes a question to be considered, in each instance, on its own merits. But the fact still remains, that for each adult or child in health, 40 to 60 cubic feet of fresh air must be estimated as provided, either by arrangement or surreptitiously, for each minute they may occupy a room or place, although not necessarily during each minute of the day and night. This fresh air must be derived from out of doors.

Accept, for the sake of argument, the average temperature and dew point of Philadelphia, in January, February and March of 1844, as reported in Prof. Bache's meteorological and magnetic observations. The mean temperature of those three months was 34°, with an average dew point of 25°, barometer 30 inches from hourly observations, giving 68·8 per cent. of saturation. Using Guyot's Psychrometrical Tables, Regnault's data, 1·57 grains of aqueous vapor exist in a cubic foot of such air. These, in Philadelphia at this season, are the unquestioned properties of the air, from which is to be furnished the fresh air of ventilation. If heated to 70° without increment of moisture, the dew point remains unchanged, and the same 1·57 grains of moisture appertain to the enlarged volume of air, now increased 8·2 per cent. by expansion. The hygrometric condition of this air is but 1·44 grains per cubic foot, or but 18 per cent. of saturation. The summer hygrometric condition of air can be derived from the same source. The three months of July, August and September give 71° average temperature, with 60° dew point, or 68·3 per cent. of saturation. Suppose we take the 68·3 per cent., and consider it the proper condition for the air of ventilation at 70°; it then follows that 5·46 grains of moisture should accompany each cubic foot of air in winter. One more step in calculation, and I have done. A cubic foot of air at 70° weighs 0·074 lbs., and if it has been elevated in temperature from 34° or 36°, then 0·635 unit of heat will have been expended in warming the air. Again, if the amount of moisture present in this cubic foot of air has been increased from 1·44 grains to 5·46 grains = 4·02 grains, then 0·612 unit of heat will have been expended in evaporation of water to supply the moisture to vaporize the air. The quantity of heat for warming very nearly corresponds with the quantity of heat for vaporization!! The tension of vapor of the external air at 34°, with 25° dew point, is 0·155

inch of mercury; that at 70°, with 59° dew point, is 0·515 inch of mercury. It follows that the pressure tending to diffuse the aqueous vapor from the "hydrated" room to the external air, would be 0·365 inch of mercury. The vapor itself, within the room at the same time, possesses but one-forty-eighth the tension of that of the air present, and hence, as it is endeavoring to escape under the pressure of about 25 lbs. per square foot (which corresponds to the 0·365 inch of mercury column), it becomes evident that it would diffuse through cracks, outlets, and even through the passages for supply of fresh air, with great rapidity, and that this ratio of saturation is practically impossible to maintain in any *ventilated* room, or even in any room whatever, as ordinarily enclosed and built.

These estimates and considerations show fairly what would result from the attempt to produce an artificial summer climate in the houses of our Northern states in winter; but while the futility of the effort in its complete accomplishment is made evident by them, it by no means follows that some degree of hydration of warmed air is not the requisite of health or of comfort, and the question recurs, what proportionate hydration is needed for these ends?

[To be continued.]

ELEMENTARY SPECTRAL HARMONIES.—II.

By Pliny E. Chase, LL.D.

[Continued from Vol. lxxiv, p. 288.]

The interferences of harmonic undulations, which are supposed to be influential in planetary aggregation and elementary molecular grouping, should be most obvious in the spectral lines which are most prominent. Hence, we can hardly hope to find any more conclusive evidence of such interference than is presented by the figurate harmonies of alternate Fraunhofer lines, the subordinate harmonies of intermediate lines, and the exponential embodiment of the same fundamental series in the solar system.[1]

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[1] This Journal, Vol. lxxiv, p. 284

The multitude of faint and microscopic lines in the solar spectrum is so great that a variety of apparent harmonies might be readily found, of which many would be reasonably open to the suspicion of merely accidental coincidence, and it would be difficult to find any satisfactory criterion for distinguishing the true from the casual. We may, however, fairly presume that the elementary spectra offer a good field for preliminary investigation, and that such observations as give the least number of lines are especially worthy of early study. Such accordances as are found in groups which have been already measured, may become valuable guides in the formation of future groups, and means may, perhaps, be thus devised for co-ordinating the investigations of Clarke, Cooke, Gibbs, Hinrichs, Kopp, Mendelejeff, Wrede and Wurtz, and opening a new world for scientific exploration.

The wave-measurements, in all of the following comparisons, are taken from the paper of Professor Wolcott Gibbs, in the *American Journal of Science*, second series, vol. xlvii, pp. 198, *seq.* Kirchhoff's lines are indicated by K; Huggins's, by H; Gibbs's groupings of corresponding lines, in the observations of both Kirchhoff and Huggins, by K H; the left hand columns containing Kirchhoff's estimates, and the right hand columns those of Huggins:

MERCURY, K H.

Wave-Lengths.		Quotients.		Theoretical.	
568·47	568·55	1·0000		1·0000	1
546·33	546·13	1·0407	1·0411	1·0406	$1 + 6a$
542·80	542·80	1·0473	1·0484	1·0474	$1 + 7a$

LEAD, K H.

Wave-Lengths.		Quotients.		Theoretical.	
561·29	561·46	1·0000		1·0000	1
537·71	537·85	1·0439	1·0439	1·0440	$1 + 3a$
439·07	438·93	1·2784	1·2792	1·2784	$1 + 19a$

LITHIUM, H.

Wave-Lengths.	Quotients.	Theoretical.	
610·73	1·0000	1·0000	1
479·48	1·2277	1·2214	$1 + 2a$
459·93	1·3279	1·3321	$1 + 3a$

Ruthenium and Iridium, K.

Wave-Lengths.	Quotients.	Theoretical.	
635·45	1·0000	1·0000	1
545·44	1·1650	1·1646	1 + 5 *a*
530·52	1·1973	1·1975	1 + 6 *a*

Chromium, K.

Wave-Lengths.	Quotients.	Theoretical.	
541·35	1·0000	1·0000	1
521·20	1·0387	1·0387	1 + 111 *a*
520·98	1·0391	1·0391	1 + 112 *a*
520·83	1·0394	1·0394	1 + 113 *a*

Copper, K.

Wave-Lengths.	Quotients.	Theoretical.	
578·67	1·0000	1·0000	1
529·30	1·0933	1·0914	1 + 6 *a*
522·24	1·1070	1·1066	1 + 7 *a*
465·64	1·2428	1·2437	1 + 16 *a*

Arsenic, K H.

Wave-Lengths.		Quotients.		Theoretical.	
617 54	617·67	1·0000		1·0000	1
611·69	611·67	1·0096	1·0098	1·0093	1 + *a*
578·95	578·73	1·0667	1·0673	1·0650	1 + 7 *a*
533·55	533·41	1·1566	1·1580	1·1579	1 + 17 *a*

Magnesium, K.

Wave-Lengths.	Quotients.	Theoretical.	
518·73	1·0000	1·0000	1
517·64	1·0021	1·0020	1 + 2 *a*
517·17	1·0030	1·0030	1 + 3 *a*
459·62	1·1286	1·1285	1 + 9 *b*
448·57	1·1564	1·1570	1 + 11 *b*
448·39	1·1569		

Tin, K H.

Wave-Lengths.		Quotients.		Theoretical.	
645·83	645·27	1·0000		1·0000	1
615·59		1·0491		1·0530	1 + *a*
556·83		1·1598		1·1590	1 + 3 *a*
556·59		1·1604		1·1620	1 + 2 *b*
510·55	510·40	1·2650	1·2642	1·2650	1 + 5 *a*
459·47		1·4056		1·4050	1 + 5 *b*
453·41		1·4244		1·4240	1 + 8 *a*

POTASSIUM, H.

Wave-Lengths.	Quotients.	Theoretical.	
630·85	1·0000	1.0000	1
624·81	1·0097	1·0097	$1 + \frac{1}{3} a$
613·25	1·0287	1·0291	$1 + a$
583·78	1·0806	1·0802	$1 + c$
581·79	1·0843	1·0843	$1 + b$
580·80	1·0862	1·0872	$1 + 3a$
551·96	1·1430	1·1454	$1 + 5a$
483·18	1·3360	1·3371	$1 + 4b$
438·96	1·4372	1·4362	$1 + 15a$
431·16	1·4632	1·4653	$1 + 16a$
426·00	1·4809	1·4810	$1 + 6c$
418·77	1·5064	1·5057	$1 + 6b$

SILVER, K H.

Wave-Lengths.		Quotients.		Theoretical.	
547·55	547·44	1·0000		1·0000	1
546·96	546·63	1·0011	1·0015	1·0013	$1 + a$
521·32	521·34	1·0503	1·0501	1·0502	$1 + 38a$

This cannot be regarded as a satisfactory accordance.

ZINC, K H.

Wave-Lengths.		Quotients.		Theoretical.	
636·99	637·37	1·0000		1·0000	1
610·64	610·89	1·0432	1·0442	1·0390	$1 + a$
589·90	589·90	1·0798	1·0805	1·0781	$1 + 2a$
472·25	471·98	1·3488	1·3504	1·3513	$1 + 9a$

CADMIUM, K H.

Wave-Lengths.		Quotients.		Theoretical.	
647·22	647·08	1·0000		1·0000	1
644·59		1·0041		1·0041	$1 + a \div 28$
531·27	531·01	1·2182	1·2186	1·2300	$1 + 2a$
509·00	508·83	1·2715	1·2717	1·2727	$1 + 5b$
480·56	480·27	1·3468	1·3473	1·3450	$1 + 3a$
468·10		1·3826		1·3818	$1 + 7b$
441·94	441·81	1·4645	1·4646	1·4600	$1 + 4a$

The quotient of Kirchhoff's sixth wave-length by the seventh (468·10 ÷ 441·94), is equal to the quotient of the fourth by the fifth (509 ÷

480·56 = 1·0592). The harmonic denominators, $1 + 7c$, $1 + 11c$, $1 + 15c$—if $c = 311·6$—give 1·2181, 1·3428, 1·4674; but this is not so satisfactory a representation, on the whole, as the one I have adopted. $(2 + 3 + 4)a = (5 + 2 \times 7)b$.

Lanthanum, K.

Wave-Lengths.	Quotients.	Theoretical.	
538·56	1·0000	1·0000	1
538·43	1·0003	1·0003	$1 + \frac{1}{4}a$
538·00	1·0011	1·0011	$1 + a$
534·48	1·0077	1·0077	$1 + 7a$
520·80	1·0341	1·0340	$1 + 31a$
519·20	1·0373	1·0373	$1 + 34a$
518·69	1·0383	1·0384	$1 + 35a$
481·59	1·1183	1·1183	$1 + 108a$

Sodium, H.

Wave-Lengths.	Quotients.	Theoretical.		
616·74	1·0000	1·0000	1	
616·56	1·0002			
590·04	1·0452	1·0455	$1 + 6a$	$(6 = 1 + 5)$
589·43	1·0462			
569·46	1·0830	1·0835	$1 + 11a$	$(11 = 1 + 2 \times 5)$
568·90	1·0840			
515·90	1·1954			
515·37	1·1966	1·1973	$1 + 26a$	$(26 = 1 + 5 \times 5)$
498·87	1·2362	1·2362	$1 + 31a$	$(31 = 1 + 6 \times 5)$

Antimony, K H.

Wave-Lengths.		Quotients.		Theoretical.	
630·84	630·49	1·0000		1·0000	1
613·50	613·73	1·0283	1·0273	1·0270	$1 + 2a$
598·41	598·72	1·0542	1·0531	1·0540	$1 + 4a$
591·61	591·45	1·0663	1·0660		
589·76	589·76	1·0697	1·0691	1·0675	$1 + 5a$
564·54	564·41	1·1174	1·1171	1·1165	$1 + 3b$
557·19	557·18	1·1322	1·1316	1·1350	$1 + 10a$
546·61	546·33	1·1554	1·1540	1·1553	$1 + 4b$
471·10	471·03	1·3391	1·3385	1·3375	$1 + 25a$

ARSENIC, K.

Wave-Lengths.	Quotients.	Theoretical.	
617·54	1·0000	1·0000	1
611·69	1·0096	1·0093	$1 + a$
603·38	1·0235	1·0244	$1 + 2b$
578·95	1·0666	1·0653	$1 + 7a$
558·29	1·1063	1·1096	$1 + 9b$
550·42	1·1219	1·1217	$1 + 10b$
538·75	1·1462	1·1461	$1 + 12b$
533·55	1·1574	1·1585	$1 + 17a$
521·32	1·1846	1·1826	$1 + 15b$

The sixth quotient is also very nearly $1·1212 = 1 + 13a$; or $13a = 10b$.

BARIUM, K H.

Wave-Lengths.		Quotients.		Theoretical.	
650·24	650·44	1·0000		1·0000	1
611·75	612·15	1·0629	1 0625	1·0634	$1 + 4a$
603·08	602·70	1·0782	1·0792	1·0792	$1 + 5a$
597·05	597·58	1·0891	1·0885	1·0890	$1 + 15c$
585·51	585·67	1·1106	1·1106	1·1109	$1 + 7a$
582·88	582·77	1·1156	1·1161	1·1159	$1 + 2b$
578·51	578·00	1·1240	1·1253	1·1246	$1 + 21c$
553·95	554·06	1·1738	1·1740	1·1739	$1 + 3b$
552·40	552·06	1·1771	1·1782	1·1780	$1 + 30c$
493·78	493·57	1·3168	1·3178	1·3168	$1 + 20a$
490·20	490·23	1·3265	1·3268	1·3264	$1 + 55c$

The eighth quotient is also very nearly $1 + 11a = 1·1742$; or $11a = 3b$.

STRONTIUM, K H.

Wave-Lengths.		Quotients.		Theoretical.	
641·38	641·39	1·0000		1·0000	
553·90	553·74	1·1579	1·1583	1·1592	$1 + d$
552·57	552·38	1·1607	1·1614	1·1610	$1 + e$
550·83	550·61	1·1645	1·1649	1·1647	$1 + 3a$
549·11	549·78	1·1680	1·1666	1·1675	$1 + 3b$
548·68	548·75	1·1689	1·1686	1·1691	$1 + 3c$
525·98	525·95	1·2194	1·2195	1·2195	$1 + 4a$
524·18	524·26	1·2236	1·2234	1·2234	$1 + 4b$
523·24	523·23	1·2258	1·2258	1·2255	$1 + 4c$
522·97	522·83	1·2264	1·2268	1·2266	$1 + \rho d$
522·71	522·60	1·2270	1·2273	1·2272	$1 + \sqrt{2}e$

The ratio between the first and the ninth harmonic increment, $\rho = 1{\cdot}4232$, is my theoretical value for the ratio between heat of constant pressure and heat of constant volume;[1] the ratio between the second and the tenth harmonic increment, $\sqrt{2}$, is the ratio between dissociative- or wave-velocity, and stable- or circular-velocity. The geometric mean of 1·1645, 1·1680, 1·1689, is $1{\cdot}1671 = 1 + 3 \times 557{\cdot}16$; $(1{\cdot}2194 \times 1{\cdot}2236 \times 1{\cdot}2258)^{\frac{1}{3}} = 1{\cdot}2229 = 1 + 4 \times 557{\cdot}16$. Huggins's means are not so theoretically exact, but their deviation is far within the limits of probable error, for $(1{\cdot}1649 \times 1{\cdot}1666 \times 1{\cdot}1688)^{\frac{1}{3}} = 1{\cdot}1668$; $(1{\cdot}2195 \times 1{\cdot}2234 \times 1{\cdot}2258)^{\frac{1}{3}} = 1{\cdot}2229$; $1 + 3 \times 556{\cdot}8 = 1{\cdot}1670$; $1 + 4 \times 556{\cdot}8 = 1{\cdot}2227$. Kirchhoff gives the following additional lines:

(2) STRONTIUM, K.

Wave-Lengths.	Quotients.	Theoretical.	
650·68	·9857		
554·52	1·1566		
461·69	1·3892	1·3893	$1 + 4\,a'$
461·62	1·3894	1·3898	$1 + 4\,b'$
431·38	1·4868	1·4867	$1 + 5\,a'$
431·18	1·4875	1·4872	$1 + 5\,b'$

PLATINUM, K H.

Wave-Lengths.		Quotients.		Theoretical.	
598·22	598·14	1·0000		1·0000	
596·86	596·59	1·0023	1·0026	1·0026	$1 + 3\,a$
595·62	595·47	1·0044	1·0045	1·0044	$1 + 5\,a$
548·07	547·95	1·0915	1·0916	1·0910	$1 + 5\,b$
530·70	530·76	1·1272	1·1270	1·1275	$1 + 7\,b$
523·10	523·08	1·1436	1·1435	1·1419	$1 + 7\,c$
506·43	506·32	1·1812	1·1813	1·1825	$1 + 9\,c$
456·19	454·92	1·3113	1·3148	1·3129	$1 + 20\,d$
450·77	449·72	1·3271	1·3300	1·3285	$1 + 21\,d$
445·65	444·45	1·3424	1·3455	1·3442	$1 + 22\,d$

This is not given among the comparisons in Gibbs's Table XI, but it embraces all the lines in which Huggins's measurements (Table IV) and Kirchhoff's (Table IX) differ by less than a unit. The groups may be connected by the equations, $21\,a = b$; $10\,b = 9\,c$; $6\,b = 7\,d$.

[1] *Proc. Soc. Phil. Amer.*, xiv, 651.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[1]

By Dr. A. Hofmann.

From the *Chemical News.*

[Continued from Vol. lxxiv, page 402.]

Compounds of Nitrogen.

Ammonia and Ammoniacal Salts.—By M. Seidel, Director of a Manufactory in Amsterdam.—Although in the report of the London Exhibition of 1862 it was justly asserted that the ammonia manufacture was still in the same condition as in 1851, there has been, during the last ten years, an essential alteration, and this branch of industry has been developed in an unexpected manner, both technically and commercially.

Up to 1860, the manufacture of ammoniacal salts was trifling in proportion to the existing supply of the raw material. The price of the products was too low to stimulate an increased production, and the technical manipulations were generally of a very primitive character.

Latterly, and especially since 1870, the use of the sulphate of ammonia for agricultural purposes has increased year by year, and both the technical and the commercial evolution of the manufacture have kept pace with the growing demand.

Among the ammoniacal salts met with in commerce, the sulphate has a quite preponderating importance, and is used almost exclusively in agriculture or in the manufacture of alum.

The use of caustic ammonia has also greatly increased, but, on the other hand, the consumption of sal-ammoniac, both sublimed and crystallized, has greatly fallen off, so that in many establishments the plant for this branch has been removed, and replaced by apparatus for the production of the sulphate of ammonia.

The sources of ammonia have remained essentially the same.

The first rank is still occupied by the so-called ammoniacal liquor or gas-water from the gas-works, in comparison with which all the other raw materials may be said completely to vanish.

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[1] "Berichte über die Entwickelung der Chemischen Industrie während des letzten Jahrzehends."

The quantity of ammoniacal salts obtained from the by-products of the prussiate of potash works, from the manufacture of animal charcoal, and from putrid urine, etc., form but a very small fraction of the total production.

Proposals for opening up new sources of ammonia have certainly not been wanting. Thus Hunt[i] patented, in England, a process for obtaining sal-ammoniac by passing a mixture of hydrochloric acid and nitrogen (or air) over ignited coke, previously saturated with ferric or manganous chloride. This is merely the resuscitation of a proposal made eighteen years ago by R. Wagner,[ii] the only difference being that Hunt uses salts of manganese, whilst Wagner recommends a salt of magnesia. The process has not hitherto obtained industrial importance. The same may be said concerning Hutchinson's[iii] process, which consists in distilling the nitrogenous residues of the starch manufacture in retorts, along with lime or caustic soda. Brief mention must also be made of the method of Coste and Paupin de Rosnay,[iv] for utilizing the ammonia of canal water.[v] The water is to be mixed with magnesia and a soluble phosphate, the precipitate of ammoniaco-phosphate of magnesia is to be collected, dried, and ignited with lime in retorts. The ammonia given off is conducted into an acid, whilst the residue is utilized as manure. In this case also the matter has not gone beyond the experimental stage.

Preparation of Ammonia from Gas-Liquor.—The ammoniacal liquor, which collects partly in the condensers and partly in the washing apparatus of gas-works, consists of a mixture of volatile and fixed salts of ammonia in very variable proportions. Among the former are ammonium sulphide and carbonate and free ammonia, whilst the latter consist mainly of the ammonium salts of sulpho-cyanogen and hyposulphurous acid, along with traces of the sulphate and chloride. The total percentage of ammoniacal compounds

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[i] Hunt, *Chem. News*, 1864, ix, 62.

[ii] R. Wagner, *Wagner's Jahresberichte*, 1856, 83; 1857, 122.

[iii] Hutchinson, *Chem. News*, 1864, ix, 31.

[iv] Coste et Paupin de Rosnay, *Ann. d. Génie Civil*, 1867, 807; *Monit. Scientifique*, 1868, 516; *Deutsche Industrie Zeitung*, 1868, 298.

[v] The water in question is probably that of Dutch canals which receive the sewage of the streets through which they pass. The same process has been patented in England for the treatment of sewage.—Ed. *C. N.*

fluctuates greatly, but as it is to the advantage of the gas works to absorb the ammonia as far as practicable, and as concentration of the gas-liquor increases its values, it is now generally delivered stronger than was formerly the case.

The approximate valuation of the ammoniacal liquor is effected by means of a hydrometer, but as the specific gravity of the liquor is essentially affected both by the quality of the water originally used and by the presence of foreign constituents, the hydrometric valuation is very uncertain, as will appear from the following table, in which samples of gas-liquor of equal value, according to the hydrometer, but different in strength according to analysis, are grouped together.

Degrees Beaumé at 15° C.

2°	2·50°	3°	3·50°	4°	4·50°	5°	6°
1·16	1·30						
1·42	1·43						
1·50	1·63	1·63					
1·77	1·77	1·76	1·87				
	1·98	1·90	2·00				
	2·18	2·10	2·24				
	2·65	2·38	2·40	2·55			
		2·45	2·72	2·72	2·79		
				2·90	2·85		
				3·40	3·06		
					3·40		
					3·53	3·67	3·74

The percentage of fixed ammonia is, on the average, 0·3, whether the hydrometer indicates a higher or a lower degree. The percentage of sulphur ranges from 0·33 to 0·50.

The utilization of the liquor is generally effected by expelling the gas by distillation in iron boilers, which are heated either by direct fire or by steam, air being simultaneously forced in [J. Braby[1] and J. Baggs]. Certain English manufacturers make use of apparatus resembling the scrubbers at gas-works in which the gas-liquor flows down from above, whilst the steam, at a high tension, rises up from below—a process objectionable in so far that such establishments can

[1] J. Braby, *Chem. News*, xx, 182.

either not use lime at all, or must employ it under unfavorable circumstances.[1]

In the establishment of Messrs. Van der Elst & Matthes, of Amsterdam, the ammoniacal liquors from most of the Dutch gas-works are treated for sulphate of ammonia as follows, having been brought by water in barges specially constructed :

The liquor is distilled in iron stills, holding from 35 to 50 hectolitres each, and heated by steam, which is furnished by five steam boilers of 30 horse-power each. The stills are fixed at the same level, and are grouped in pairs, which can be worked alternately, being connected by reciprocating cocks.

The volatile constituents are first distilled off without the addition of lime, and then the quantity of milk of lime required for the decomposition of the fixed ammoniacal salts is driven in by steam pressure. The products of distillation pass first into a collecting vessel, and from here through 5-inch (13-centimetre) valve-cocks into large receivers filled with sulphuric acid, in which the ammonia is absorbed without the slightest loss, since the cocks are so arranged that the products may be conducted at will into one or the other receiver.

The residual watery vapor, plentifully contaminated with sulphureted hydrogen and carbonic acid, is removed from the receivers by a special chimney fitted with an arrangement for burning the sulphureted hydrogen.

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[1] The following description of the apparatus used in the manufacture of caustic ammonia at the works of Messrs. Jaffé & Darmstädter, of Berlin, has been communicated to the editor by Dr. L. Darmstädter. It consists of three superposed boilers, containing about 50 hectolitres, the two lower being heated by direct fire, and provided with agitators, to ensure a perfect commixture of the lime and the gas-liquor, and to prevent the lime from burning to the bottom of the boiler. The upper boiler serves as a preparatory heater, and, to a certain extent, as a dephlegmator. The gas from the third boiler is passed, for the removal of watery vapor, through an arrangement of Liebig's condensers as extended as possible, and, preferably, 20 to 25 metres in length, from which it finally escapes into the washing bottles and condensing apparatus, which are connected together by means of a tube filled with wood charcoal, for the absorption of any residual empyreumatic matter. By a sufficient length of the pipes, and by the interposition of more washing bottles, it is possible to obtain chemically-pure ammonia. In the manufacture of caustic ammonia, it is of course essential to introduce into the still, before the commencement of the operation, the whole of the lime needful for decomposition, as otherwise the resulting product may be easily contaminated by volatile ammoniacal compounds, such as ammonium sulphide and carbonate.

The escaping vapor, on its way to the chimney, traverses prolonged series of pipes, which raise the temperature of the gas-liquor about to be distilled to 50° or 60°. Besides an important economy in fuel, this arrangement produces the further advantage, that the gaseous mixture deposits a great part of its watery vapor, which greatly facilitates the combustion of the sulphureted hydrogen.

The annual production at the works of Van der Elst & Matthes amounts to about 1200 tons sulphate of ammonia.

All establishments where gas-liquor is treated in quantity, are compelled to pay great attention to the pernicious emanations which are inseparably connected with this manufacture.

Unless proper precautions are taken, not alone the residents in the neighborhood suffer from the copious development of sulphureted hydrogen, but the men employed in the works are attacked with violent inflammation of the eyes.

The progress made in this direction consists, principally, in the improvement of the burners for the combustion of the noxious gas, and the construction of chimneys with increased draft.

The Compagnie Parisienne d'éclairage et de chauffage par le gaz, which, in its three large establishments, produces yearly about 3000 tons sulphate of ammonia, and, in addition, large quantities of caustic ammonia, has described, in a special treatise,[1] the arrangements adopted for the sanitary improvement of its works.

As another important improvement, must be mentioned the safety-valves which are now attached to every still. Although, under ordinary circumstances, these apparatuses work at a very low pressure, obstructions may nevertheless be produced, in the gas delivery-tubes, under a variety of circumstances, and may easily occasion explosions, such as took place, in 1867, at the establishments of Van der Elst & Matthes, of Amsterdam, and of Kunheim & Co., of Berlin. These dangers are, once for all, obviated by the introduction of safety-valves.

Ammonia and Ammoniacal Salts.

By M. SEIDEL, Director of a Manufactory in Amsterdam.

Applications of Ammonia.—As already mentioned, the consumption of sulphate of ammonia in agriculture has become more and more established. In comparison with guano, and with all putrescent

[1] Note relative aux divers produits et aux ouvrages exposés à Vienne par la Compagnie Parisienne.

manurial matters, this salt has the great advantage that all its ammonia is combined, and, although in consequence of this fact the effect is less rapid than that of guano, it is decidedly more permanent.[i]

The production of caustic ammonia likewise has manifestly increased. Large quantities are required by Carré's ice-machine, which, although still encumbered with a variety of defects, is daily finding a more extended application.[ii]

Caustic ammonia is also more and more required in the tinctorial arts, and very recently it has unexpectedly come into use in the preparation of indigo in Java.

According to the old process for the preparation of the color from various species of *Indigofera*, lime was added to the fermenting mass. A Belgian chemist, J. Sayers, of Djocjocarta, in Java, has introduced there a new process. Instead of lime he adds ammonia during the fermentation, and is said in this manner to obtain a purer color.

The successful resumption of the method tried more than thirty years ago to produce soda by treating chloride of sodium with carbonate of ammonia, has also lately given a considerable impulse to the manufacture of ammonia. Should, as it almost appears, the ammonia-soda process come into use on a larger scale this circumstance would very essentially contribute to a further development of ammonia manufacture.[iii]

The condensibility of ammonia and its great solubility in water, have inspired the idea of using it as a motive power for machinery.

The earliest experiments in this direction are due to Tellier and Flandrin.[iv] In connection with these attempts Tellier has subsequently

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[i] Recently repeated attempts have been made to extract by direct lixiviation, the ammonia which accumulates in the composition employed in gas-works for purifying purposes (bog-iron ore and saw-dust) and to utilize it as manure. In consequence, however, of the abundant presence of sulphocyanide in the sulphate, and of its pernicious action upon vegetation, these experiments have led to no favorable result.—Private communication, of Dr. L. Darmstädter to the editor.)

[ii] Compare the paper by Dr. Meidinger in an earlier portion of this report.

[iii] According to private communications which the editor has received from German manufacturers, an increase of the demand for carbonate of ammonia, in consequence of its application to the ammonia-soda process, is as yet scarcely perceptible.—(A. W. H.)

[iv] Tellier and Flandrin, *Comptes Rendus*, lx, 59; *Monit. Scientifique*, 1865, 134; *Dingl. Pol. Journ.*, clxxvi, 163; *Deutsch. Industrie Zeitung*, 1865, 126; *Wagner Jahresber.*, 1865, 279.

sought to make ammonia useful in a variety of technological applications, but without arriving at any decided success, which may be partially due to the circumstance that the commercial value of ammonia has so greatly increased of late years. Tellier has collected his suggestions and published them in a separate work—"L'Ammoniaque dans l'Industrie." Paris: J. Rothschild, 1867. Delaporte[i] also has patented an ammonia machine in France.[ii]

We may, in conclusion, briefly mention a few proposals respecting the preparation of various ammoniacal compounds.

As is well known, ammonia is fixed not only by acids, but by many salts, which, in this case, play the part of an acid. These compounds, which have been experimentally examined by H. Rose, Persoz, and Rammelsberg, give off the ammonia when heated, a property which is often used in the laboratory for the preparation of liquefied ammonia. Latterly Knab[iii] has proposed to obtain such saline compounds of ammonia industrially, and to store up the gas in this form. Such compounds would then only require a gentle heat in order to evolve a current of dry ammoniacal gas. Chloride of calcium can in this manner take up 50 per cent. of its weight of ammonia, whilst strong liquid ammonia contains only 20 per cent. of dry ammonia. This latter assertion is an error, since water, even at 15°, is capable of taking up more than 30 per cent. of its weight of ammoniacal gas.

Ammonium sulphide, so frequently employed for analytical purposes, has been hitherto almost exclusively prepared by passing sulphureted hydrogen into caustic ammonia. It is now obtained by Spence[iv] industrially by mixing ammonium sulphate or chloride with twice its weight of alkali-waste or gas-lime, exposing the mixture to the action of steam, and condensing the products of distillation in suitable apparatus.

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i Delaporte, *Génie Indust.*, August, 1865, 63.

ii Lamm, of New Orleans, is said (*Engineer*, Jan., 1875) to have constructed an ammonia-machine, which has been successfully tried for street tramways; the chief difficulty, the loss of ammonia, is almost overcome by the use of an oil joint in the stuffing boxes.

iii Knab, *Chem. News*, 1866, xiii, 192; *Deutsche Industrie Zeitung*, 1866, 178; *Wagner Jahresber.*, 1866, 205.

iv Spence, *Mech. Mag.*, Nov., 1866, 307; *Dingl. Pol. Journ.*, clxxxiii, 397; *Polyt. Centralb.*, 1867, 461.

Kunheim[i] has introduced a simple, but under certain circumstances very advantageous, improvement in the manufacture of ammonium carbonate. Previously this salt had been almost exclusively prepared by the double decomposition of sal-ammoniac and carbonate of lime, the chloride of calcium, relatively worthless, being obtained as by-product. Kunheim employs, instead of carbonate of lime, the carbonate of baryta, and obtains a solution of baric chloride, which may be advantageously used in the preparation of permanent white.

Nitric Acid and its Salts.

By Dr. ADOLPH GEYGER, of Berlin.

Even at the commencement of the present century, a part of the saltpetre consumed in the various countries of Europe came from India as so-called exotic saltpetre,[ii] and the rest of the supply was obtained as native saltpetre by the lixiviation of natural or artificial nitre beds.

The consumption of nitrates in the chemical arts, and in the manufacture of gunpowder, and of other blasting materials, has increased to such an extent that the earlier sources became utterly insufficient. A new supply was laid open in the vast deposit of a mineral very rich in nitrate of soda, discovered more than fifty years ago in the district of Tampa, on the border between Chili and Peru.[iii] The extraction of this deposit is still on the increase, and furnishes by far the largest part of the raw material for the nitrates now used in the arts.

According to the statements of Dr. G. Langbein[iv] there were in the year 1871 in the Peruvian nitre districts, eleven large refineries with a daily production of about 6000 cwts. purified nitrate of soda. The nitriferous mineral, called *caliche*, is found in beds from 0·25 to 1·5 metres in thickness, which, however, rarely rise to the surface. The superincumbent rock, *costra*, is from ½ to 2 metres in thickness, and consists principally of a hard conglomerate of sand, feldspar, phosphates, and other minerals. The composition of the *caliche* fluctu-

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i Kunheim, *Deutsche Indust. Zeit.*, 1866, 178; *Chem. News*, 1866, xiii, 192; *Wagner Jahresber.*, 1866, 202.

ii The terms exotic and native saltpetre are not known in the English trade.—Ed. *C. N.*

iii Rivere, *Schweigger's Journ.*, xxxiv, 450.

iv Langbein, *Wagner's Jahresber.*, 1871, 300, and 1872, 290.

ates; it contains 48 to 75 per cent. nitrate of soda, 20 to 40 per cent. chloride of sodium, and varying quantities of sulphates of soda and lime, nitrate and iodate of potassa, chloride of magnesium, etc., as also insoluble earthy matters and organic substances (guano). It is first broken up in a disintegrator and placed in the dissolving pans. Some of the establishments use long four-sided cisterns, but the better arranged works use closed egg-shaped boilers provided with two movable covers, of which the upper serves for the introduction of the *caliche*, and the lower for the removal of the exhausted material. The mass rests upon a perforated false floor, fixed at about one-fourth the height of the boiler, and consisting of four pieces, movable on hinges. The boilers are filled up to the top with the broken raw material, and up to half height with mother-liquor, and are heated by the direct action of steam, which is admitted by four pipes reaching below the false bottom. In from one and a quarter to two and a half hours the liquid is sufficiently saturated with nitre and is let off into settling tanks; after some hours' rest the clear liquor flows into flat crystallizers, fixed in an open place and exposed to the wind. Latterly a second settling-tank has been interpolated, in which the liquid is allowed to remain for about half an hour, in order to deposit the common salt which is held in mechanical suspension before being run into the crystallizers.

The residue left in the boilers, which still contains from 15 to 35 per cent. soda saltpetre, is either cleared out at once or extracted once more with spring water. The closed boilers are simply emptied by letting down the lower or true bottom, when the residue falls into wagons run in beneath, and is drawn away from the works. The crystals of nitre which form in the crystallizing pans after the mother-liquor is drained away, are spread upon a large surface exposed to the wind, and called *cencha*, in layers of from 30 to 50 centimetres in thickness, and dried by being frequently turned over. The total cost of 1 cwt. of Chilian saltpetre up to its conveyance to Europe was calculated in the year 1871 by Langbein, as follows:—

Cost of production,	3·25	marks
Conveyance to the coast,	2·40	"
Cost of shipping,	0·25	"
Freight to Europe,	2·75	"
Charges on arrival,	0·25	"
	8·90	"

or about 8*s*. 8*d*.

W. Lloyd,[i] in 1868, calculated the cost of production at 8·40 marks per cwt. The rise of price in spite of the improvements in the process of purification, is due to the enormous increase in the cost of labor and in the freight to the Port Iquique. Although the saltpetre districts have been now for some years connected with the port by a railway, the greatest part of the produce is still conveyed upon mules.

The exportation of nitre is still constantly on the increase, as the following figures prove:—

1830,	18,700 cwts.
1835,	140,399 "
1840,	227,362 "
1850,	511,845 "
1860,	1,370,248 "
1870,	2,943,413 "
1871,	3,605,906 "
1872,	Upwards of 4 million "

By the decree of July 12th, 1873, the Peruvian Government has taken the saltpetre trade into its own hands, and has fixed the quantity that may be yearly exported at 4½ million cwts. As to the effect of this monopoly upon the saltpetre trade, no decision can as yet be formed.

As a specimen of the composition of the purified soda saltpetre, as imported into Europe, the following very complete analysis, published by Wagner,[ii] may be cited:—

Sodium nitrate,	94·03
" nitrite,	0·31
" chloride,	1·52
" sulphate,	0·92
" iodate,	0·29
Potassium chloride,	0·64
Magnesium chloride,	0·93
Boracic acid,	trace
Moisture,	1·36
	100·00

The mother-liquor of the refineries contains from 2½ to 5 grms. iodine per litre, and is used in some Peruvian establishments as a source of that body. (Compare chapter on Chlorine, Bromine, and Iodine.)

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i Lloyd, *Wagner's Jahresber.*, 1869, 247.

ii R. Wagner, *Wagner's Jahresber.*, 1869, 248.

As to the origin of these saltpetre beds in Peru, various explorers have published their opinions, but without giving a fully satisfactory explanation. Indeed it would almost seem as if the formation had taken place under circumstances which have remained hitherto unknown. According to H. Reck,[i] Chili saltpetre is the oxidation product of large guano beds, whereby, however, as Nöllner very justly remarks, it remains unexplained what can have come of the great mass of sparingly soluble phosphate of lime, whilst the readily soluble nitrate of soda remains behind.[ii]

The hypothesis of C. Nöllner[iii] possesses the greatest amount of probability. He believes that in consequence of storms, prodigious masses of seaweed, all nitrogenous, have been driven into that bay of South America, and have given rise to nitrate of soda by a process of slow oxidation.

In support of his view Nöllner adduces the constant occurrence of iodine in the nitrates, and concludes, therefore, that their origin can be due only to seaweeds, those nitrogenous collectors of oceanic iodine. The geographical position of the saltpetre beds agrees, in fact, very well with this theory, since on this coast west winds blowing from the sea predominate, their action being supported by the currents flowing along the coast. If these westerly winds only a few times in the course of centuries became violent hurricanes, and threw colossal masses of seaweeds collected from the enormous surface of the Pacific upon the land, which is entirely rainless, and consists of a parched-up plain or a hilly alluvium, a zone of seaweeds would be formed exactly as represented by the nitre-beds of Peru. We should, of course, have to assume that the nitre when formed was withdrawn from the action of the waves by volcanic elevation or by the retrocession of the sea. The small percentage of potassium in Chilian nitre corresponds with the proportion of potash in the seaweeds, and the constant occurrence of boro-sodio-calcite reminds us of the boriferous minerals in rock-salt and in deposits of potassium chloride.

[To be continued.]

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i H. Reck, *Berg- u. Hütten-Zeit.*, 1863, 188, 207, 225, 229; Wagner, *Wagner's Jahresber.*, 1863, 303.

ii Without wishing to advocate the guano theory, we may point out that the *costra*, or superincumbent rock, has just been described as consisting in part of phosphates. —Ed. *Chem. News*.

iii C. Nöllner, *Journ. Prakt. Chemie*, cii, 459; *Wagner Jahresber.*, 1868, 290.

NOTE ON THE THEORETICAL EXPLANATION OF FRAUNHOFER'S LINES.

By HENRY HARTSHORNE.

Professor Henry Draper, in his recent paper upon the "Discovery of Oxygen in the Sun by Photography," etc., indicates his conclusion that the theory of the constitution of the solar spectrum must be modified, in view of the facts presented in his investigations. This conclusion is obviously true, so far, at least, as regards the demonstration of the existence of oxygen, and the great probability of that of several other substances not hitherto therein recognized, in the sun. But some other modification of the accepted theory of the spectrum, it appears to the writer, is also demanded by the same and by some other now known facts.

Professor Draper suggests that "the reason of the non-appearance of a dark line may be that the intensity of the light from a great thickness of ignited oxygen overpowers the effect of the photosphere." He adds that "such an explanation would necessitate the hypothesis that ignited gases, such as oxygen, give forth a relatively large proportion of the solar light."

This is a hypothesis of so considerable violence, in view of familiar facts, that there is room to examine whether another explanation may not be arrived at, which will include all the facts, some of which Professor Draper's observations seem to have brought into contradiction. Of course, the opposition cannot be in the facts themselves, but must be in our views of them. The apparent contradiction referred to is thus alluded to by Professor Draper: "At first sight it seems rather difficult to believe that an ignited gas in the solar envelope should not be indicated by dark lines in the solar spectrum, and should appear not to act under the law 'a gas when ignited absorbs rays of the same refrangibility as those it emits.'" Then follows this important remark: "the substances hitherto investigated in the sun are really metallic vapors, Hydrogen probably coming under that rule. The non-metals obviously may behave differently." It is then added, "it is easy to speculate on the causes of such behavior." In the way of speculation thus indicated, the only suggestion

made is that above quoted, regarding the possibly great thickness of ignited oxygen overpowering the effect of the photosphere. Another view of the facts now under remark appears to the writer more consistent with the whole history of the solar spectrum; although not less opposed to the commonly accepted mode of statement, according to which the dark lines are accounted for by an ignited gas "*absorbing* rays of the same refrangibility as those it emits."

In a paper read before the American Philosophical Society, April 21st, 1876,[i] after a description and proposed explanation of some facts concerning ocular spectra, I remarked of those facts, that "they have a definite relation to the mode of production of the Fraunhofer lines or 'absorption bands' of the spectroscope." Further thought upon the same and other phenomena induces me to believe that a definite relation of the kind indicated may now be referred to, as, along with Professor Draper's observations, giving ground for proposing a totally different view of the causation of Fraunhofer's lines from that which has been hitherto universally accepted.

It will hardly be necessary to remind the readers of this JOURNAL of the nature of the ordinary explanation, by "absorption," beyond the account of it contained in the words cited above from Professor Draper's article. Since Kirchhoff's announcement of this explanation, in 1859, it has been practically undisputed. Professor Stokes very early proposed to illustrate it by the analogy of the "absorption" of sonorous vibrations. Tyndall describes this illustration as follows: "A stretched string responds to aerial vibrations which synchronize with its own. A great number of such strings stretched in space would roughly represent a medium; and if the note common to them all were sounded at a distance, they would absorb the vibrations corresponding to that note. That is to say, *they would absorb the vibrations which they can emit.*"

While sensible of the boldness of such a demurrer, I must submit that this illustration is not exactly *applicable* to the case of Fraunhofer's lines. The same may be said of another version of the proposed analogy, which has been given by Professor Lommel, of Erlangen.[ii] The latter reads as follows: "If a large number of tuning

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[i] "On Some Disputed Points in Physiological Optics," *Proceedings of Am. Philosophical Society*, 1876.

[ii] "On The Nature of Light," etc.; 1876, p. 252.

forks be imagined to be attached to a table, and a sound wave unisonal with them be excited at one end, it will reach the other in a very weakened condition, because its energy will have been in great measure absorbed by the tuning forks. A wave of another pitch will, on the contrary, traverse the layer of tuning forks almost unaltered, and will spread beyond them without noticeable loss."[1]

Prof. Lommel adds that the undulatory theory thus affords an explanation of absorption, inasmuch as it shows that "every body must absorb exactly those kinds of luminous rays which it is itself capable of emitting."

This last statement, taken by itself, is undoubtedly true; and, in regard to sound, especially, it has been admirably illustrated by Tyndall and others, by many experiments. But, there are two *conceivable* kinds, or cases of so-called absorption. One is that of the above experiments, with *silent* stretched strings, or *silent* tuning forks, which are *made to vibrate* in resonance with the vibration of a string, or a fork, when that is struck so as to elicit its tone, with which that of the others corresponds. The *other* case, strictly analogous to that of the Fraunhofer line-phenomena which need to be explained, should be that of undulations emanating from a vibrating string, or tuning fork, which undulations, impinging upon other consonant strings or forks *already in vibration*, will be thereby *weakened* and *annulled.*

Supposing this result really to follow in such an experiment, it would still bear another mode of description and explanation. But, for brevity, I will at once approach the positive view which appears to me preferable in regard to Fraunhofer's lines.

Obviously, it is altogether correct to say, with Prof. Lommel and others, that "ignited vapors are *opaque* for rays of their own kind, while perfectly permeable to all other kinds of rays." If Kirchhoff's discovery and explanation of the meaning of the dark lines of the solar spectrum had gone no farther than this, it would have been, as it is, a magnificent contribution to science, on account of its immediate and various applications in chemistry and astronomy. Without access to Kirchhoff's original papers (Berlin Academy, 1859), I am unable to ascertain whether his expressions did or did not include the

[1] The use of the word "*imagined*" in this account by Prof. Lommel, suggests the query: Has *precisely this* experiment ever been actually *tried?*

idea of "absorption" as conveyed in the citations above made from Stokes, Tyndall and Lommel.

But the view which I wish to propose may be distinctly expressed, by substituting for *absorption* the word *interference.* Since my paper, above mentioned, was printed, I have met with a retrospective account, by Prof. J. W. Draper,[1] of his early observations upon the spectrum. In this retrospect, Prof. Draper mentions that, in photographing the solar spectrum to fix the Fraunhofer lines, he "allowed *daylight to fall along with* the sun rays on the photographic surface. The *daylight and the sunlight antagonized each other*," and thus "ultra-spectrum heat lines," beyond the red, appeared as positive photographs. He mentions, also, that Foucault and Fizeau, in 1846, reported the existence of the same "ultra-spectrum" lines, and stated their observation (as Draper says) of "*the antagonizing action* above described." Another experimenter, about the same time, failed to obtain these heat lines beyond the red, on account of his *exclusion of diffused daylight* from the photographic surface.

With so eminent an authority employing expressions such as have just been cited from Prof. J. W. Draper, it cannot be called presumption, nor even novelty, to speak of *interference*, in connection with the phenomena of the spectrum. Not feeling competent to deal with the more abstruse theoretical questions at once raised by the demand for the reconciliation of this "case" (if it be such) of interference, with the classical instances rendered so familiar by Huyghens, Young, Fresnel and others, I must content myself with one or two further suggestions here.

Experiments to exhibit the interference of vibrations, either of sound or light, are as yet, considering the importance of the inquiry, not very numerous. The subject is one but incompletely studied. As Lommel states, the reason why interference by *direct opposition* of equal rays is not demonstrable, is that we cannot secure sufficient accuracy in the equivalence of opposition. Irregularities will occur. But, while light-waves travel through space at the rate of 186,000 miles per second, it is inconceivable that *interference by direct and diffusive opposition* should not at times occur. In the case of a luminous burning solid, surrounded by its own glowing vapor, the

[1] *Harper's Magazine*, April, 1877, p. 898, *et seq.*

simplest view is that the undulations emanating from the luminous centre are met, opposed and partially annulled by the *antagonizing action* of the equivalent vibrations of the glowing vapor particles. Here especially we may notice, with Prof. Henry Draper, that "all the substances hitherto investigated in the sun are really metallic vapors, hydrogen probably coming under that rule." At least, then, in the case of all but hydrogen, it is conceivable that *luminous particles*, capable of *returning interfering* vibrations in the paths of those emanating from the central sun-mass, exist in the photosphere. It does not need that all, or nearly all, of the sun's emanating vibrations, in any one path, should be thus neutralized by interference. On this point, we need only to remember that the "dark" lines are only *relatively, not absolutely, dark.* Prof. J. W. Draper observed, long ago (*Phil. Magazine*, 1843), and many others have noticed since, that there is a great difference, at different times and under various circumstances, in the *relative visibility* of the Fraunhofer lines.

In regard to hydrogen, it may be observed that the special character of its molecular constitution and susceptibility of movement, shown by chemical relations to ally it to metallic substances, may be readily believed to affect it like them in its relations to the vibrations of light; even although our acquaintance with it does not favor the supposition of its containing, like the metallic vapors, particles capable of becoming visibly luminous to us.

It would seem, then, not too much to say, that, with the re-opening by Prof. H. Draper's discovery and some other new facts, of the question as to the *theory of the spectrum*, the subject of interference needs to be further investigated; and, particularly, what may be called *crass* interference, or that of the direct opposition of luminous waves, or rays, in *diffused* light.

As bearing incidentally upon this general topic of interference, I may now mention some facts quite recently observed. If before anywhere reported, they have, I think, not yet found their place in current treatises. They may be designated as phenomena of *cross lights.*

1. In a square room, let diffused daylight be admitted from windows on two sides, say the north and west, so as to fall upon a sheet of white paper about equally distant from the two windows. Two shadows of an object, such as the hand held over the paper, will then be

thrown upon the paper; one will be ***rose or pink-red***, and the other *bluish-green*. In my observations, the shadow made by the north light is bluish or greenish, and that by the west light, orange or reddish. Other instances, however, of crossed-daylight shadows occur, where the two shadows thrown are, respectively, blue and orange.[i]

2. When a student's kerosene lamp is burning in a room, just before sunset, so that the lamplight and that of a window will make two shadows of an object, one of these shadows (that thrown by the window light) will be orange, and the other (thrown by the lamp) blue.

3. Let the light of a full moon and that of a student's lamp so fall in a room upon a white surface, that they will throw upon it shadows of about equal intensity, in nearly opposite, or at least different, directions. One of these shadows, of a hand, for instance, or of a stick, will be reddish-orange, viz., that thrown by the moonlight; the other, thrown by the lamplight, greenish-blue.

Whatever difficulties of application may appear, in theory, concerning "half-wave lengths," "opposing phases of undulation," etc., in endeavoring to explain these and many other phenomena, of complementary shadow-tints, spectra, etc.,[ii] no other term appears to me to be appropriate to them but *interference*. It may be, and no doubt is, very often, in such cases, only a partial arrest of light-waves that occurs, with relative obscuration, or color change. Especially in the case of the Fraunhofer lines, as contrasted with such definitely measurable examples as those of the "colors of thin plates," there may be some advantage in the distinction attempted to be conveyed by the expression, *crass* interference.[iii]

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[i] In all these cases, the colors of the shadows are not intense, or they would have been very often noticed. They are, however, quite clearly distinguishable, by persons having ordinary normal sight. A certain *proportion* of the cross lights is, of course, necessary; I have seen the complementary shadows, in the daytime, only with *diffused* daylight; not under the direct rays of the sun.

[ii] See my paper above referred to, in *Proceedings of Am. Philosophical Society*, April 21, 1876.

[iii] The word *crass* is from the Latin, through the German; meaning nearly, though not precisely, the same as *gross*.

APPARATUS FOR PRODUCING ELECTRIC LIGHT.

By Gustave Trouvé, M.E.

The attention which I have given to the subject of lighting by dynamo-electric machines, has for its end the securing of much greater efficiency to all machines.

Electro-magnets, in their operation, deviating but little from the law of gravitation, I have thought that their action should be effected under similar conditions. I have, therefore, been led to working always by contact, in order to obtain the greatest possible efficiency.

In ordinary machines,[1] the effects are commonly produced at a great distance; hence there results a great loss, as, for example, in the Gramme machine. Some work under better conditions, the electro-magnets acting in closer proximity. Nevertheless, the distance necessary for the play of the parts always occasions a loss, which may be estimated in the ratio of about 1 to 8, if there is contact, a loss which would be much less if the magnetic circuit was complete, as well as the electric circuit.

The principle which I have patented, and which is applicable with remarkable generality, aims at combining these two conditions of maximum, consequently augmenting the effect in a notable degree.

I will briefly describe a machine, arranged for acting in accordance with my principle:

The machine is composed of two or more electro-magnets in permanent magnetic contact, and participating in a rotary movement, like the trains of a rolling mill. The magnetic and electric circuits are, therefore, closed, which can be said of no other machine.

This arrangement fulfils the two conditions of maximum above named. The magnetic contact being constant, the machine never needs priming. Small machines, built on this plan, operate as well as large machines. This has been, hitherto, impossible, because they did not retain enough residuary magnetism.

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[1] We may except the Laade machine, in which the Siemens bobbin acts in magnetic contact. But it has a slipping friction so rapid, that it is transformed into heat, rendering continuous action almost impossible. In my machine, on the contrary, all the frictions are rolling.

In the accompanying sketch I have represented only the parts essential for the successful application of my principle, purposely omitting the important, but well-known, accessories.

The application of the principle requiring the play of all the parts, the entrance and exit of the currents is made through the axles, which are hollow, and admit in the centre the insulated conductors, of which the extremities are seen at t, t', t'', t''', t'''', t''''', t''''''.

Figs. 1 and 1′ represent front and side views of a machine, composed of a strong, straight electro-magnet, influencing a series of straight electro-magnets, and forming a circular bundle. The whole system

Fig. 1.

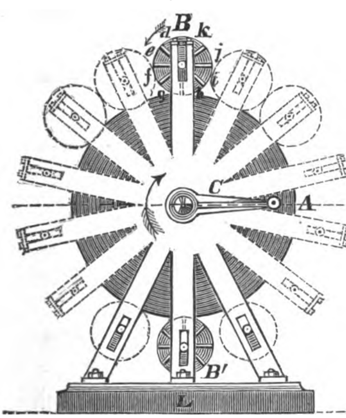
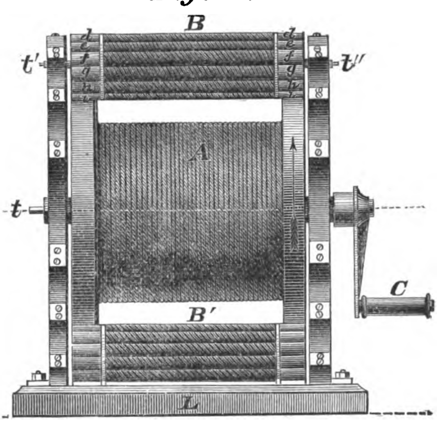


Fig. 1′.



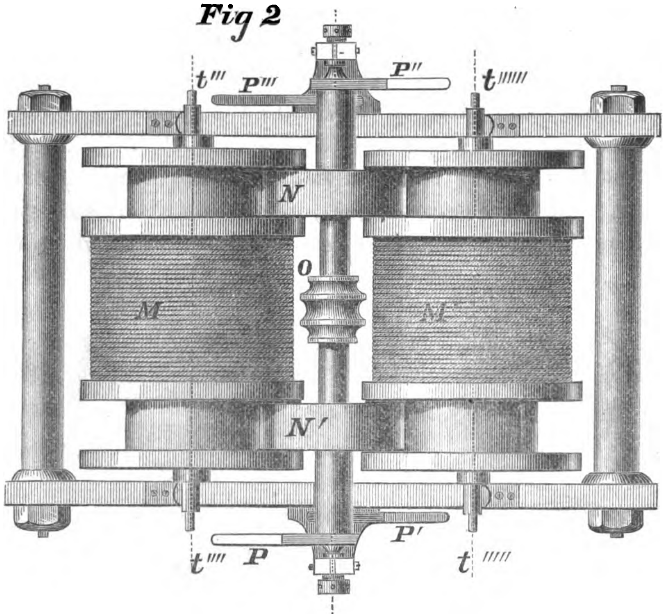
is set in rotary motion by the great electro-magnet, which also serves as a regulator. The machine can give either reciprocating or continuous currents, like the Gramme machine, according to the arrangement of the commutator. It is either magneto- or dynamo-electric, according as an electro-magnet or a permanent magnet is employed.

If the motion is such as indicated by the arrow, all the electro-magnets, *d*, *e*, *f*, *g*, placed at the left of the perpendicular, passing by the centre or axis, approach the great electro-magnet, which affects them, and generates, in their respective bobbins, positive currents; all the electro-magnets on the right of the perpendicular, *h*, *i*, *j*, *k*, receding from the great electro-magnet, are influenced by negative currents. A special commutator collects these currents, either to use them in quantity or in derivation, or to give them in tension.

Fig. 2 represents a Gramme machine, arranged on this principle. It is evident that the two electro-magnets, *M*, *M′*, are in permanent

contact, by their opposite poles, with the two discs N, N', thus forming a single magnet, for which one of the discs serves as a shank,

Fig 2



and the other as an armature, constituting, as I have said, a completely closed magnetic circuit.

Fig. 3 represents, in section, one of the two discs, N, N', which are mounted on the common axle, O. When they are set in motion they communicate a rotary movement to the two electro-magnets, which influence them continually, and thus generate currents in the series of bobbins which form the discs. The contact becomes more complete, between M, M', and N, N', in proportion as the currents are stronger; in other words, as the speed of the machine increases.

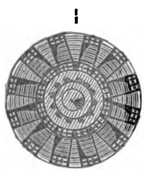


Fig. 3

REFERENCE.

Figs. 1 and 1′. *A*, large electro-magnet, serving as fly-wheel, moved by the crank, *C*, or by a pulley mounted on its axle.

B, *B′*, cluster formed of the small electro-magnets, *d*, *e*, *f*, *g*, *h*, *i*, *j*, *k*.

C, crank.

L, support.

Fig. 2. *N*, *N′*, modified Gramme discs, moving the two electro-magnets, *M*, *M′*, which influence them.

O, pulleys to set the axle in motion.

P, *P′*, *P″*, *P‴*, friction springs, collecting the currents which are generated in the discs.

t, *t′*, *t″*, etc., extremities of the coils of the electro-magnets.

Fig. 3. Section, in the plane of motion, of the modified Gramme disc.

This machine can easily yield, for each of its discs, a light equivalent to 600 carcel burners, in every way suitable for demonstrating the principle. The two electro-magnets, *M*, *M′*, can be separated at pleasure from magnetic contact with the two discs, *N*, *N′*, and the diminished intensity of the current will be immediately seen.

RELATIVE COST OF WATER- AND STEAM-POWER.

By Henry P. M. Birkinbine.

When erroneous statements are put into print, it is almost impossible to correct them. An evidence of this is presented in an assertion contained in the article, under the above head, in the Journal for December, page 388: "The cost of raising water by water-power at the Fairmount Works in Philadelphia is but *two cents per one million gallons*, raised one foot high."

In an article published in the Journal for May, 1876, page 323, the commercial value of Fairmount water-power is presented, and figures given, taken from the reports of the Water Department, which show that, as compared with steam, the water pumped by the water-power works was, at a cost of from $13,000 to $19,500 per annum, above what it would have cost to have done the work by steam, with pumping engines of the same average efficiency as those in the works.

The two cents referred to, as the cost of raising one million gallons, one foot, by water-power, were expended for simply running the works, that is, attendants, oil, tallow, and ordinary repairs; it does

not represent the entire cost of operating the works; it leaves out of consideration the extraordinary repairs, incident to water-powers, those of maintaining the dam, head-race, gates, etc.

The water-power at Fairmount has cost the city of Philadelphia between one, and one and a quarter millions of dollars, for water-rights, damages, dam, head-race, mill-houses, wheels, and pumps. The precise cost is difficult to ascertain, as many of the expenditures were made in connection with other work. Taking the interest of one million dollars ($60,000), as the annual cost of the power, and dividing it by the water pumped in 1876, 8,374,657,743 gallons lifted into the reservoirs, it will show that the power alone cost over eight cents per million gallons, lifted one foot. To this must be added the running expense, two cents, and also the cost of extraordinary repairs, incident upon maintaining the dam, head-race, etc. It is therefore evident that the cost of raising water at Fairmount by water-power, is between ten and twelve cents per million gallons, one foot.

The water-power on the Schuylkill, next above Fairmount, at Manayunk, owned by the Schuylkill Navigation Company, and leased to eighteen different manufacturing establishments, has a power equal to one thousand horses; and for this power the company receives a yearly rental of $43,100, or $43.10 per horse power, per annum. Even at this low figure, it is a question which is the cheapest, water or steam, when the annoyance of low water, floods, and interferences of the navigation are taken into account. Were this power now unoccupied, the yearly rental would not warrant its utilization, simply for a water-power.

Since the steam engine has been brought to the degree of perfection, in simplicity, efficiency, economy, and reliability, that we now have it, there are few locations in the thickly settled portions of our country, where fuel can be procured at a moderate price, that water-power will be found cheaper or more desirable than steam-power. This is particularly the case where the water-power is unfavorably located, and where the trouble, incident to drought, floods, etc., is taken into account. There are unimproved water-powers in this vicinity, and many which have been improved are now unemployed and allowed to go to decay.

Philadelphia, December 13*th*, 1877.

ON THE EMPLOYMENT OF ZINC IN BOILERS AS A PREVENTIVE OF FRESH WATER SCALE.

By Brossard de Corbigny, Mining Engineer.

[Translated from the *Annales des Mines*, of 1877, for the Journal of the Franklin Institute, by Chief Engineer Isherwood, U. S. Navy.]

Mr. Lesueur, formerly an employee of the telegraphic companies, has presented to the Minister of Public Works, and also to the Academy of Sciences, a memoir relative to the employment of zinc in steam boilers as a scale preventive. The author, in that document, relates the circumstances which led him to an examination of this question. During the repairs of a steamer at Havre, in 1861, after several years' service, it was observed with surprise, that, while one of her boilers, fed with sea-water direct from the sea, was almost wholly oxidized and useless, the other two, fed with water from the condenser, were in perfect preservation, and that some brass partitions in the condenser were reduced to the state of pure spongy copper, the zinc of the alloy having entirely disappeared. From these facts arose the supposition that zinc could be employed as a scale preventive; and since 1873, Mr. Lesueur has been engaged in bringing it into common use, or at least in having it tried by a great number of manufacturers at Angers, and in the department of Maine-et-Loire. Under these circumstances, the Minister of Public Works ordered us on the 16th of October, 1876, to closely observe these trials, ascertain the value of the process, discover the cause of the action of the zinc, and find out the best method of applying it.

We will here state that a great number of recommendations had been furnished by manufacturers who had tried the use of zinc, and that, independently of those given in the memoir, others were sent to us; the owners of the boilers which we examined also confirmed the favorable results, with very rare exceptions, whose cause we have still to find. We limit ourselves to the mere mentioning of these things, and shall hereafter deal only with what we have ourselves discovered.

We will investigate successively:

1. The material facts attending the use of zinc.
2. Their explanation.

3. The influence of the nature of the water used in the boilers.
4. The precautions to be taken in practice.

1. THE MODE OF ACTION OF ZINC.—The application of the process consists in simply placing a quantity of zinc in any part of the boiler farthest removed from the furnace; whether the zinc shall be in large or small masses, must be determined by the circumstances of each particular case. The boiler being then filled, is continued in operation during the ordinary time, and when cleaned, if the kind of water used produces calcareous deposits, the following will be observed:

When the water is but little calcareous, the deposits, instead of forming solid and adherent scale, remain in the state of fluid-mud, easily removable by simple washing. The iron being clean and not rusted, no picking or scraping is needed, which effects a great economy of time, hand-labor and oversight.

When, however, the water is strongly calcareous, the deposits are as coherent and stony as though the zinc had not been employed; but what is extremely important, this scale, while acquiring its thickness and hardness, does not adhere to the iron. It can be pulled off by hand, or, at the worst, detached without much effort, leaving the iron clean. A simple washing removes it from the boiler, and in this case, as in the previous, picking and scraping are avoided.

As regards the zinc itself, it is not strictly correct to say it has disappeared; but it has been transformed, *in situ*, into its oxide, a white and earthy substance, which often preserves the lamellar texture of the metal, the central part sometimes continuing metallic and unattacked. Evidently there has been a slow oxidation, and time has occasionally been wanting for a complete metamorphosis of the zinc into oxide of zinc. A specimen taken from the Desert Mine boilers (Maine-et-Loire), fed with water from the river Loire, gave, on analysis, the following composition:

Water,	1·60
Oxide of Zinc,	87·30
Oxides of Iron and Aluminum,	3·80
Sand and Clay,	1·60
Carbonate of Lime,	6·20
Carbonate of Magnesia,	0·50
	101·00

On the other hand, no trace of dissolved zinc was found in the water taken from the boilers; and but very feeble quantities were found in the scale deposited from this water. To determine this last fact, we have analyzed the solid and abundant scale formed in the boilers of the Raynaly works of Angers. These boilers were fed from a well, near the river Maine; and their scale had the following composition:

Carbonate of Lime,	75·60
Carbonate of Magnesia,	3·00
Sulphate of Lime,	9·35
Sand and Clay,	8·40
Oxides of Iron and Zinc,	4·20
Chlorides,	0·40
	100·95

It is indubitable that the oxide of zinc was dragged by the water currents, and thus mechanically mixed with the scale. Two kinds of deposit are, therefore, formed under these circumstances, and they must be distinguished from each other: the one derived from the feed-water, and precipitated in the usual manner of scale upon the water-heating surfaces, but without adhering to them; the other formed almost wholly of the oxide of zinc, and remaining entirely, or nearly so, where the metal was placed. The water taken from the boiler when it was cleaned, contained, after filtration, no trace of metal. Some specimens of water taken from the boilers of the Raynaly and the Laboulais works at Angers, and from those of the Desert and Legal Mines at Nantes, having been treated with the sulphohydrate of ammonia, gave no appearance of coloration or reaction.

The results are very different when the boilers are fed with selenious water, instead of the calcareous water used in the foregoing cases. We have established the following at the slate works of Angers, and with three boilers (La Paperie, les Petits-Carreaux, and l'Hermitage).

The feed-water, generally drawn from old abandoned excavations, is extremely hard, and its deposits consist essentially of the sulphate of lime, colored by a little oxide of iron. The presence of this salt in water traversing only schistose formations is explained by the fact that the slaty schist contains numerous crystals of iron pyrites, transforming, under the influence of air and moisture, into sulphate of iron, which reacts in its turn upon the lime contained, in small

proportion, in the schist, and in some calcareous veins running through it, forming sulphate of lime holding only traces of iron; these traces are so feeble that the water is not colored by the sulphohydrate of ammonia, but the oxide of that iron, being concentrated in the deposits, colors them a light pink.

When the water is used without a scale preventive, the sulphate of lime is deposited in the form of mud, of which only a part adheres to the iron, forming a thin crust of scale having the following composition by analysis:

Sulphate of Lime, ...	88·00
Sulphate of Iron, ...	2·70
Ferruginous Clay and Sand, . . .	4·50
Water, ...	4·60
	99·80

The abundance of the gypsum-mud compels such frequent cleaning of the boilers (every month or six weeks) that the scale has not time to acquire much thickness.

The addition of zinc has not given any valuable result; at the most, the scale has been observed to be a little less thick with its concave surface flat and glossy, in place of being undulating; but its adhesion to the iron was strong, requiring picking and scraping to remove it; so that after over a year of fruitless efforts, the employment of zinc has been discontinued. Perhaps not enough metal was used, but if this kind of water, highly charged with scale-producing salts, requires too large a quantity, there would be no economic advantage in the use of zinc.

2. Theoretical Explanation.—The preceding data enable us to frame a theory of the phenomena. Mr. Lesueur, in his memoir, explains them as electrical effects, of which, however, he does not clearly define the action, and which, at the first glance, do not appear to be justified; nevertheless, we believe his explanation is correct, and sufficient to account for the phenomena observed.

We must begin with the fact that the zinc, not being dissolved, and consequently not being brought into contact with the boiler surfaces, does not act as a coating or as an emulsion which mechanically prevents the adherence of the scale. The zinc undergoes oxidation, and

can obtain its oxygen only from the air dissolved in the feed-water, or from the oxygen constituent of that water: the first hypothesis leads to no satisfactory explanation; the second, on the contrary, involves the following: The two metals, iron and zinc, surrounded by water at a high temperature, form a voltaic pile with a single liquid, which slowly decomposes the water. The liberated oxygen combines with the most oxidizable metal—the zinc—and its hydrogen equivalent is disengaged at the surface of the iron. There is thus generated over the whole extent of the iron influenced, a very feeble but continuous current of hydrogen, and the bubbles of this gas isolate at each instant the metallic surface from the scale-forming substance. If there is but little of the latter, it is penetrated by these bubbles, and reduced to mud; if there is more, coherent scale is produced, which, being kept off by the intervening stratum of hydrogen, takes the form of the iron surface, without adhering to it.

Experience has shown that for about three months' use of a boiler, during twelve hours per day, one pound of zinc should be employed for each five square feet of water-heating surface. The pound of zinc requires 24·628 pounds of oxygen for its saturation, and this oxygen is combined in the water with 3·0785 pounds of hydrogen, occupying in the gaseous form, at the temperature of 32° Fahr., and under the standard atmospheric pressure, 550·5 cubic feet, which, in the boiler, is reduced in the direct ratio of the boiler pressure, making the bulk of hydrogen, for a pressure of five atmospheres, say 110 cubic feet. This is the volume of hydrogen which would be employed during about three months, or, say, 1100 hours' use, to maintain a thin gaseous stratum, interposed between five square feet of iron and the scale. The quantity, though certainly small, we believe sufficiently large to justify our explanation. The presence of this small quantity of hydrogen could never be a source of danger to the boiler, though doubtless it would form, in proper proportions, an explosible mixture.

But how explain why the same effect was not produced with the selenious water of the slate works of Angers? Should it be attributed to the more coherent nature of pure sulphate of lime, or to an insufficient quantity of zinc employed? We cannot, at present, pronounce with certainty on that point, and limit ourselves to simply reporting the facts established by observation.

The hypothesis we have framed is, furthermore, confirmed by the following fact mentioned in the memoir of Mr. Lesueur, but which we have not had an opportunity to verify: Zinc introduced into a boiler whose surfaces had been imperfectly freed of scale, has the property of detaching the remainder. This effect is well explained by the action of a feeble disengagement of gas beneath the scale, raising it little by little, and separating it from the iron.

3. INFLUENCE OF THE KIND OF FEED-WATER USED.—The foregoing already gives an idea of this influence, which we make more precise by the following remarks:

A. SOFT WATER TYPE. *Boilers of the Desert Mines fed with water from the river Loire.*—This water, when treated with nitrate of silver, gives a light precipitate of chloride of barium, and nitrate of ammonia; not anything when treated with lime-water; it marks 8½ hydrometric degrees.

The employment of one and a half pounds of zinc per ten square feet of water heating surface, permits a boiler to be used during three or four months without forming scale; the deposit has no adhesion, and can be removed by simply washing out the boiler.

Boilers of the Laboulais Works at Angers, fed with water from the river Maine.—The effect of treatment with nitrate of silver was a little more marked, and a slight action was produced by lime-water; hydrometric degrees, 16. The employment of one pound of zinc for each ten square feet of water heating surface, permits a boiler to be used for several months. The deposit does not cohere, and can be removed by simply washing out the boiler.

Boilers of the Engines pumping water for the city of Angers, at the bridge of Cé.—These boilers are fed with the same water, and produce the same results as in the case of those of the Desert Mines.

B. CALCAREOUS WATER TYPE.—*Boiler at the Raynaly Works, at Angers, fed with water from the river Maine.*—This water comes from the Maine through about 330 feet of debris of demolished buildings, and gave abundant precipitates by the ordinary reagents; hydrometric degrees, 40. The scale was essentially calcareous, and in some places three-fourths of an inch thick, but it was not adherent to the iron, from which it came off easily. Chippings of zinc had been employed in the small proportion of two-thirds of a pound for every ten feet of water heating surface.

Boiler of the Legal Works at the City of Nantes.—This boiler was fed with water similar to the immediately preceding, but of only 27 hydrometric degrees. We have not seen these works, which are beyond our district, but we know, by a letter from the proprietor, that he is well satisfied with the results obtained in a tubular boiler of twelve horse-power.

C. SELENIOUS WATER TYPE. *Boilers of the Slate Works at the City of Angers.*—The feed-water of these boilers, when treated with the nitrate of silver, gave abundant precipitates of chloride of barium and of oxalate of ammonia, but none when treated with lime water. It was essentially selenious and non-calcareous, as explained by its origin, and marked from 40 to 45 hydrometric degrees. It formed a very hard scale of sulphate of lime. No sensible effect was produced by the employment of zinc in moderate quantities, and no trials were made with large quantities.

We have not been able to investigate two other types of water, which do not occur in our district, namely, sea water and acid water. The first would require special observations, and with the second no good result could be attained. In fact, the zinc would be rapidly dissolved in a solution of free acid strong enough to corrode the iron—as we have witnessed on other occasions—and at the end of a few days it would have disappeared, if employed in only sufficient quantity to saturate the feed-water, a consumption incompatible with an economic use.

Neither the type nor the form of the boilers appears to have any influence on the results. Our observations were principally made on plain cylindrical boilers, but several proprietors of tubular boilers have testified to the good effects obtained in them.

4. MANNER OF EMPLOYING THE ZINC, AND PRECAUTIONS TO BE TAKEN.—Our observations show that it is certainly better to employ the zinc in pigs or cubical masses, than in chippings or sheets. In the second case the electro-chemical action, being exerted over too large a surface, becomes too rapidly exhausted, while with cubical masses it is better graduated, and the metal more economically used.

The zinc can be placed on any part of the boiler, except the surfaces exposed to the radiant heat of the furnace; on them its pasty oxide causes burning and blistering, of which we have seen examples.

The end of the boiler most remote from the furnace appears to be the best place to put the metal.

The quantity of zinc to be employed depends obviously on the hardness of the water, on its rate of vaporization, and on the intervals between renewal. In circumstances where the process gives good results, one pound for every five square feet of water-heating surface should be considered the maximum; the one-half pound stated by the author of the memoir, is only sufficient for very soft water, or for very short periods.

It is scarcely necessary to remark that the employment of zinc cannot diminish the quantity of deposit from any given feed-water. We should not have mentioned this, had not some proprietors of boilers seemed to think they had effected the more or less disappearance of these deposits, although they could only have caused the diminution of their cohesion and adhesion to the surfaces. Others (Heilmann at Mulhouse, and the owners of the Desert Mine) apprehend that the valves and cocks of the boilers will be worn by the pulverulent scale, swept along by the steam currents, which evil could doubtless be remedied by means of a steam-drum of sufficient capacity.

CONCLUSIONS.

The following are the practical conclusions of the present report:

1. The process discovered by M. Lesueur, appears to be of incontestible value with calcareous feed-water, when not too hard; that is to say, when of not more than 25 or 30 hydrometric degrees. The deposits in this case lose all cohesion, or, at least, do not adhere to the iron, the cleaning of which, by picking and scraping, is thus avoided.

2. With selenious feed-water of 40 hydrometric degrees or more, the result is insignificant.

3. No better result would be attained with feed-water containing free acid.

4. The zinc should be employed by preference in cubical masses, and in quantities of from half a pound to a pound for each five square feet of water-heating surface during several months. It should be placed at the end of the boiler the farthest from the furnace, and the boiler should be furnished with a steam-drum of sufficient capacity.

IMPROVEMENT OF THE SOUTH PASS OF THE MISSISSIPPI.[1]

By E. L. CORTHELL, Resident Engineer.

In regard to the depth of channel that exists at present through the jetties, it will be sufficient to state that on the first day of November, this year, the steamship City of Bristol, of the New York and Liverpool Inman Line, passed through the jetties without detention and without touching. Her draught was 21 feet and 8 inches, the tide at the time was 2½ inches below "average flood tide," which is the plane of reference established by the United States Engineers.

It may not be generally understood that the delay in obtaining the deeper channels, demanded by the contract between Capt. Eads and the United States Government, has been caused mainly by the difficulties which have been met with in deepening the river shoal at the head of the Passes.

First, there was not a full knowledge and comprehension of all the conditions existing, nor of their relation to each other, and to the channel, which it was necessary to make into South Pass; secondly, it was necessary that the works should be partly tentative in their nature, and this fact demanded considerable time in which to observe their effects; thirdly, many months were consumed in building these extensive works which would control the whole volume of the river. All these causes have delayed the formation of the channels through the bar at the Gulf, where the jetties are located. Without entering, beyond a few explanations, into the discussion of this most difficult and interesting problem of river hydraulics, on which a treatise could well be written, we simply refer to the fact of its existence and of its intimate relation to the channel through the jetties.

There are conditions existing of so subtle a nature, with relations so obscure, and yet so entirely dependent upon each other; there are hidden causes, that operate so quietly and easily, to change existing conditions and destroy the equilibrium of natural forces; there are at times such unlooked-for results from the works constructed, and there are so many occult principles and unknown laws in the flow of water moving in immense volumes that are elucidated by these results, that, in the end, one of the most useful and interesting histories may be

[1] *Providence Journal.*

written, that will record in detail all the steps which have been taken to persuade the water of the great river to go where man directs.

With all the interest that may attach to the subject in the mind of a disinterested person, who views it all calmly from a distance, yet by those who have not only their reputations, but their financial prospects, at stake in the success of these jetties, it is deeply regretted that the completion of the work and the securing of the maximum channel have been delayed so seriously, and the success of the enterprise endangered by what appears now to have been false economy, which decided upon the improvement of the South Pass rather than of the Southwest Pass.

To improve, by the force of river currents, a shoal which lies as a great middle ground between the two main outlets of the river, is one of the most difficult of undertakings. To induce the river to leave the channels in which it has flowed for ages, and to seek a new and untried one, is in opposition to its conservative nature; it hesitates long, and is very loth to leave the old ways for the new.

It is necessary to show this almost sentient monster that there are sound hydraulic reasons for changing its ancient habits.

All the works that are built in the funnel-shaped mouth of South Pass, have a tendency to throw a part of its volume into the two large passes, which stand right there with their great, hungry mouths to take every drop that comes within their reach.

To avoid this result of our works, it has become necessary to hold the sections of these passes *in statu quo*, by laying on their beds a sill of willow mattresses, from our works, at the head of South Pass, to the east and west banks of the river.

The total length of these sills is about one mile and a quarter. They are simply the foundations of more extensive works of the same kind, by which we expect to control, slowly but surely, the whole river volume, and draw from it, what South Pass needs to obtain and maintain, a channel, 30 feet deep and 350 feet wide, to the deep waters of the Gulf of Mexico.

Another subject which we wish to refer to, especially, is the "re-formation" of the bar in front of the jetties; that "re-formation" that has been held up by some of our friends, as the great, final and grand obstacle to our success.

In the earlier stages of the work, it was the impossibility of securing even a twenty foot channel that troubled them; the absurdity

of our expecting any such result was so clearly patent to their minds that they thought their argument unanswerable, and convinced themselves at any rate of our prospective failure; but the 20 foot channel came, then the 21, now nearly the 22, and through the jetties a broad, deep channel, from 24 feet to 95 feet deep, has made its appearance, and has thus steadily and surely furnished us facts for our arguments that 30 feet would surely come.

Of late we hear but little of the absurdity of our intention to obtain a deep channel; but now it is *that bar*, that *new* bar, that is to form so rapidly, close up the jetty outlet, and bring disaster upon the whole enterprise!

Well, it is now two years and a half since we laid the first willow mattress on the South Pass bar. The same enormous volume of mud and water has flowed out through the jetties that formerly spread out like an open fan a mile and a half in width, and in addition to it nearly four million cubic yards of sand and clay have been excavated from the shoal at the head of the Pass and from the channel between the jetties and thrown out into the gulf.

The arguments on either side have facts now, or the absence of them, to prove or disprove the conflicting theories. The time has come when the American people who are to pay for this great work can demand the facts, that they may know whether all the money expended and to be expended, is irretrievably lost in a mud bank that will pay no dividend to its depositors, or will result in a deep and permanent outlet for the Mississippi Valley.

In the limited space allowed us in your crowded columns, we cannot give all the details connected with the facts in our possession. If we could do so, and could illustrate them by maps or diagrams, we could show to the satisfaction of the most obstinent opponent of the jetties that the re-formation of the bar, as prophesied, is a myth. We will briefly allude to the facts and give general results only.

In May, 1875, the United States Coast Survey, under the direction of Mr. H. L. Marindin, one of the most efficient and careful assistants in the department, made an accurate and detailed survey of the South Pass bar. This survey extended into the Gulf about half a mile from the outer crest of the bar.

In October of this year (1877), we made a survey, covering the same ground. The lines of soundings were run in the same manner

as those of Marindin. The general and detailed plan was similar to his. The work was plotted on the same scale. His soundings were increased by one foot and eight-tenths, to bring his plane of reference up to ours.

The whole area in front of the jetties was then divided into squares of one hundred feet. We took it for granted that between any two soundings of his, and also of ours, the slope was uniform. Depths were thus obtained for each corner of each square.

A skeleton was made, on which these squares were drawn; the calculated depth at each intersection was put down in one color for Marindin's survey, and in another color for ours, and we then had the data carefully arranged for calculations by the prismoidal formula. This plan was adopted on account of the unequal spacing of the soundings, and, while it is open to the charge of interpolation, it gives, under the circumstances, the most accurate results.

The depths having thus been put down, the skeleton was subdivided into larger areas and figures. Using the one thousand feet, between the present end of the jetties, as the base of a rectangle, the jetty lines were produced into the Gulf 2500 feet.

This figure was divided again into smaller rectangles of 1000 feet by 500 feet.

The large rectangle was enlarged by adding 1000 feet to the width at the outer end (500 feet on each side), but retaining nearly the same width at the end of the jetties. Then a larger figure still was drawn in the same way, and so on, until the final figure embraced the fan-shaped area of the discharge of sedimentary matter issuing from the jetties during high river.

The calculations show that over the rectangle (1000 feet by 500 feet), lying immediately in front of the jetties and adjacent to their ends, there has been an average deepening of four feet and two inches.

This is the identical ground over which the bar re-formation was to take place so rapidly. The rectangle first spoken of, namely, 1000 feet by 2500 feet, we will call A; the next larger figure B, the next C, and so on, each one embracing all the preceding. The result of these calculations is given in the following table.

A map exhibiting graphically the changes that have taken place, shows clearly that there are well defined areas of scour entirely across the whole mile and a half investigated, and at right angles to the end of the jetties.

We do not need to go beyond this map to prove the existence of a well marked and almost constant littoral or shore current of salt water, sweeping under the fresh water, and not only carrying to one side the vast amount of sediment thrown out of the jetties, but even digging down and cutting into and carrying off much of the original outer slope of the bar.

Letter of Combination.	Area of Combination, in square feet.	Mean gain in depth of Combination, since May, 1875, in feet.	Quantity of material scoured in Combination, since May, 1875, in cubic yds.
A, ...	2,500,000	0·878	81,341
B, ...	4,000,000	0·727	107,690
C, ...	5,300,000	0·996	195,609
D, ...	6,520,000	1·144	276,328
E, ...	7,770,000	1·166	335,572

The surveys and calculations made recently by Capt. M. R. Brown, U. S. Engineers, who is detailed by the Secretary of War to inspect the jetties for the Government, corroborated the statements we have made.

In his report of July, 1877, to the Secretary of War, he compares his survey of June, 1876, with that of June, 1877.

We quote some passages that refer to this special subject, and which are found on pages 26, 27 and 28:

"On sheet No. 4 will be found the results of a survey, in June 20th, to June 22d 1877, of a mile or more beyond the ends of the jetties, and for a considerable space on either side."

"The subject of fill and scour beyond the ends of the jetties has occupied so much attention that I have carefully compared the results of the survey of June, 1876, with that of June, 1877, and for the purpose have divided the whole area, comparable by means of the two charts, into twenty-one divisions."

"The fan-shaped areas are, of course, those of the most pressing interest when investigating the influences of changes in the immediate future of commerce."

"Taking into account all the divisions except 1, 7, 13 and 21, we find that the scour in the year was 1,145,976 cubic yards, equivalent to a scour of $1\frac{3109}{10000}$ feet, or 1 foot 3·7 inches over this latter area."

A Drainage Tunnel 31½ Miles Long.—The difficulty and expense of dealing with the drainage water of the mines in the district of Freiburg, Saxony, led to the abandonment of some of the most important of them nearly a century ago, and it became evident that other mines in the same district must soon suffer from the same cause; thus threatening an industry which had been prosecuted through several centuries.

A deep adit, or drainage tunnel, was the only hope for relief, and in 1838, O. von Huber proposed and published a plan of an adit, to start from the Elbe, near Massen, and follow a straight course to Halsbrücke, 22,000 metres distant. The cost to this point, where it would drain the abandoned government mine, was to be borne by the State; but beyond this the adit was to be extended to other mines at the expense of those to be benefited.

This plan was abandoned as too costly, and requiring too great a length of time to execute, and, in 1844, the Government commenced the construction of an adit from Rothschonberg on the Elbe, about 12 kilometres above Massen, the distance to Halsbrücke being much less. The latter plan originally contemplated an adit 12,882 metres long (exclusive of 334 metres of auxiliary drain and branches), 3 metres high and the same width; and at a depth of 89 metres less than the one first proposed, but 94 metres below the deepest adit then existing, and to have seven air-shafts. The estimated cost was $950,000 gold, and the time required, twenty-two years.

A change of plan, however, increased the length of the main adit to 13,900 metres, and necessitated an eighth air-shaft, which, with unforeseen difficulties in the execution of the work, greatly increased the cost, and prolonged the time for its completion to the beginning of this year—thirty-three years from its commencement.

The length of the main adit and its branches, now completed, is 43,000 metres; but further extensions are to be made, and when finally completed the total length will be 50,900 metres, or 31·6 English miles. The cost, up to the first of January, 1876, was 2,235,897 thalers, $1,609,845.84 gold.

All but a small portion of the adit is driven through solid gneiss rock, and up to October, 1875, all the work was done by hand; since then, however, rock drills, driven by compressed air, have been introduced with great advantage, both as to progress and cost.—*Engineering and Mining Journal*, of October 27th, 1877.

Experiments upon Homogeneous Iron.—From late experiments in the dockyard of Castellamare, the following inferences are drawn: 1. That punching alters the molecular constitution of homogeneous iron. 2. That this alteration does not extend more than a millimetre from the hole. 3. That annealing is of no use if it is employed before punching, but it restores the ductility if it is employed afterwards. 4. That this advantage is lost if the holes are subsequently enlarged by a reamer. 5. That drilled holes produce no sensible alteration in the molecular structure and ductility, even if they are slightly enlarged by a reamer. Experiments are contemplated with small punches, with a diameter at least 2 mm. smaller than the holes, the holes to be subsequently enlarged by drills.—*Il Politecnico*, from *Rivista Maritima*. C.

Geodesic Accuracy.—Gen. Ibañez communicated to the International Geodesic Congress, at Stuttgart, a statement that by combining the old French angles with those of the late Spanish survey, without any geometric compensation, he obtained a value of 21933·35 m., which differs from the base of Vich, which was measured by him last summer, only 1 decimetre, or less than 4 inches.—*Comptes Rendus.* C.

Nickeled Iron.—The deposit of nickeled iron at Saint Catherine, in Brazil, is now exhausted. It was probably a meteorite with a total weight of at least 25,000 kilogrammes. It was found at a depth of 4 decimetres, under a bed of fragments of coarse-grained granite. Its weight entitles it to one of the first ranks among the known masses of meteoric iron.—*Acad. des Sci.; Les Mondes.* C.

Danger of Speed on Railroads.—Scheffler, in *Organ für die Fortschritte des Eisenbahnwesens*, 1877, Heft v, discusses the influence of speed on the number of railroad accidents. Although he finds four times as many accidents on freight trains as on express trains, and twice as many as on ordinary passenger trains, the slowest trains are not the most dangerous. After making allowance for the distance traveled, the principal kinds of accidents, and other considerations which are requisite for a true basis of comparison, he finds that the danger of bodily accident increases as the square of the speed; and the danger of injury to the track or rolling stock, as the cube of the speed.—*Wochenschrift des Oester. Ing. und Arc. Ver.* C.

Strength of Slate.—Messrs. Blavier & Brossard, mining engineers, have studied the comparative resistance to rupture of the Angers slates, marble, and Tonnerre stone. The experiments were made with slabs of about 1 metre long, ·15 to ·50 metres wide, and ·008 to ·050 metres thick. The rupturing load P was weighed, and the coefficient of rupturing resistance R was calculated by the formula,

$$\frac{P\,(b-a)}{4}=\frac{R\,l\,c^2}{6}$$

in which l is the distance between the supports, b the breadth of slab, c its thickness, and a the breadth of the ledges. The following mean values were found for R: for slate cut lengthwise, 5,621,000; slate cut crosswise, 2,733,000; marble, 1,140,000; Tonnerre stone, 630,-400. Slate has the added advantage of being easily split into slabs, while the other stones require the use of a saw.—*Ann. des P. et Chauss.* C.

Parisian Libraries.—The National Library contains more than a half million volumes. Other city libraries aggregate more than 1,100,000 volumes.—*Les Mondes.* C.

Electro-Silicic Light.—M. G. Planté has obtained very brilliant effects by placing one of the poles of a powerful secondary battery in contact with the side of a glass vase or a porcelain basin, holding a saline solution. The luminous appearances observed in glass, under induction currents, by du Moncel, Gassiot, Grove and others, also accompany the new process. The same results may be obtained by substituting rock-crystal for the glass or porcelain, but a higher power is required.—*Les Mondes.* C.

Safety of Railroad Traveling.—The *Annales des Ponts et Chaussées*, for August and September, 1877, contain two valuable articles on the "Block System" of running trains. From the second article we extract the following statistics. The average loss of life in France, in traveling by diligence, was 1 in 355,000; on railroads, from 1835 to 1855, 1 in 2,000,000; from 1855 to 1875, 1 in 6,000,000; from 1872 to 1875, 1 in 45,000,000. A person traveling constantly by railroad, for 10 hours a day, at the rate of 50 kilometres per hour, estimating a mean journey at 30 kilometres, would have had the following chances of being killed by a railroad accident: 1835 to 1855, 1 chance in 321 years; 1855 to 1875, 1 chance in 1014 years; 1872 to 1875, 1 chance in 7459 years. C.

India-Rubber Piston-Packing.—In the "Grands-Makets" Belgian coal mine, there is a cistern, with a direct-acting pump which raises the water to a height of 220 metres. The pump body was lined with metal, and the piston was packed with steel rings. The effective work sank in a few months from 80 to 25 per cent. An examination showed that the steel rings, on account of the impurities of the water, had torn the lining, and broken much of the packing. It was therefore decided to use a softer packing, and copper was tried with similar results. Rings of moderately hard caoutchouc, alternating with copper disks, were then substituted, netting 85 per cent., and avoiding the wear of lining, and consequent diminution of efficiency.—*Dingler's Journal.* C.

Industrial Teaching.—In the school of chemistry, maintained by the Industrial Society of Mulhouse, special attention is paid to the chemistry of colors, and to everything that is connected with dyeing and printing. The first year's course embraces general, mineral and organic chemistry, new products and processes, qualitative and quantitative analysis, preparation of chemical products. In the second year, special attention is given to the aromatic series, to the derivatives of coal tar which are suitable for dyeing textile fabrics, to bleaching, dressing, dyeing and printing, and to the examination of printed tissues, in order to ascertain the colors employed. The course of physics includes heat, optics and electricity, in their industrial applications; the use of the microscope and spectroscope; and such knowledge of mechanics as is indispensable for understanding the operation of machinery. The pupils visit industrial establishments, accompanied by their professors. In the school of spinning and weaving, both theoretical and practical instructions are given in designing; in the manufacture of various threads and tissues; in the study of new and improved machinery and models; in the different transformations of motion, force and work; in steam and hydraulic motors and apparatus; in heating apparatus and combustibles; in book-keeping, and in the analysis of tissues. C.

American Steam-Boilers.—The Austrian Commissioners to the Centennial Exposition are preparing very complete accounts of the several departments. From Prof. Radinger's descriptions of the steam-boilers, *Il Politecnico* extracts some interesting comments.

The height of the American chimneys varies from 20 to 60 metres; the section of escape is made from $1\frac{1}{8}$ to $1\frac{1}{4}$ times the mean section of the smoke-pipes, and is often calculated according to the following formula:

$$A = \frac{112\,N}{\sqrt{H}}, \text{ or } A' = \frac{4\,N}{\sqrt{H'}},$$

in which A, H and N represent, respectively, the section of the chimney in square inches, the height in feet, and the force of the boiler in horse powers; A' and H' represent the section and height in square decimetres and metres. The formulæ accord very closely with those of Redtenbacher and Darcet. About 100,000 boilers are used in the United States, of which about 80,000 are subject to no kind of official inspection. Explosions are frequent, due for the most part to the negligence of firemen, and to the adoption, by patentees, of objectionable forms, which render proper cleaning almost impossible. Among the tubular generators, that of Pierce is noticed, "which is the realization of one of the most curious ideas that ever sprouted in an American brain." The Corliss boiler is noteworthy for its simplicity and compactness. It might profitably be imitated in all cases where economy of space is a *sine qua non*. The dryness of its vapor is an added advantage. C.

Strength of Iron at Different Temperatures.—G. Pisati and G. Saporito-Ricca find that the strength of iron at different temperatures shows peculiar irregularities. The strength, in a wire which is exposed to a dull-red heat, diminishes with increase of temperature from 14° to 50°, then increases to 90°, diminishes rapidly to 120°, remains constant to 200°, sinks slowly to 235°; then comes a sudden increase, which is followed by a gradual diminution. The strength is greater at 300° than at 140°.—*Pogg. Ann.; Dingler's Journ.*, 225, 512. C.

Brachy Telescope.—J. Forster and K. Fritsch describe, in *Dingler's Journal*, 226, 3, a combination of two reflectors with eye-glasses, which they call a brachy telescope, uniting the advantages of Herschel's and Cassegrain's telescopes. With a mirror of 106 millimetres diameter, Fritsch has seen the double star γ Virginis, β Orionis (Regulus), η Pleiadum (Atlas), the Pole-star, and others, beautifully separated. C.

Researches in Feeble Magnetism.—P. Silow reports results of his investigations in the laboratory of Prof. Helmholtz, for determining the absolute value of the magnetizing constant of fluids. He starts from the considerations, that the study of strongly magnetized bodies shows the insufficiency of Poisson's hypothesis; that the ratio of polarizing to magnetizing power is independent of the latter, and is of a constant magnitude; and that in weakly magnetized bodies, especially in fluids, only a temporary polarization occurs He refers to the researches of W. Weber, Toepler and v. Ettingshausen, and G. Wiedermann, as confirming Poisson's first hypothesis, and as establishing laws relative to the influence of the magnetizing power, of the concentration, of the solvent, etc. He admits that the deviation of some of the results from the mean is considerable (in one instance ·138), but considers them satisfactory in view of the delicacy of the measurements.—*Ann. d. Phys. u. Chem.*, 237, 481, *seq.* C.

New Electrical Law.—Clausius announces the following general law, of which many of the known laws of electrical reciprocity are immediate consequences: Suppose any number of conductors, C_1, C_2, C_3, which neutrally influence each other. Let them be charged with electricity in two different ways; at the first charge, let the respective quantities in the different bodies be Q_1, Q_2, Q_3, etc., and the resulting potential levels V_1, V_2, V_3, etc. At the second charge let the corresponding values be $\mathfrak{Q}_1$, $\mathfrak{Q}_2$, $\mathfrak{Q}_3$, etc., $\mathfrak{V}_1$, $\mathfrak{V}_2$, $\mathfrak{V}_3$, etc. Then we shall find:

$$V_1\mathfrak{Q}_1 + V_2\mathfrak{Q}_2 + V_3\mathfrak{Q}_3 +, \text{etc.}, = \mathfrak{V}_1 Q_1 + \mathfrak{V}_2 Q_2 + \mathfrak{V}_3 Q_3 +, \text{etc.};$$

or, taking the sums, $\Sigma\ V\mathfrak{Q} = \Sigma\ \mathfrak{V}\ Q$.—*Ann. d. Ph. u. Ch.*, 237, 493. C.

Electric Conductivity in Constant Streams.—F. Kohlrausch and O. Grotrian (*Pogg. Ann.*, cliv and clix) have found values for the electric conductivity of fluids with variable streams. J. Tollinger has experimented with nine different solutions in constant streams. The percentage of the soluble ingredient varied between 2·5 and 94·5; the resistances, between 27·96 and 255·47. The differences in the results, as measured in constant and in variable streams, range between ·1 and 1·3 per cent.—*Ann. d. Ph. u. Ch.*, 237, 514. C.

Fire-Proof Flooring.—An English brewer made his malt-floor of three-inch planks grooved together. A fire broke out, the roof over the floor fell in, and the fire raged for twenty-four hours over the floor without burning through it, because the grooves prevented a supply of air from below. The security might be increased by covering the beams and the under side of the planking with fire-proof cement.—*Der pr. Masch.-Const.* C.

Variability of Orbital Major-Axes.—M. S.-C. Hareter finds that the invariability of the major-axes of planetary orbits, which Laplace, Lagrange and Poisson have established for the first and second powers of the disturbing masses, does not hold for higher powers. It may, therefore, perhaps, be found that the stability of the system requires the figurate harmony of principal planetary masses, which was pointed out in the September number of this JOURNAL, page 148.—*Comptes Rendus.* C.

Apparatus for Measuring the Work of Iron.—In the *Annales des Ponts et Chaussées* for October, 1877, M. Dupuy describes some new apparatus for the direct measurement of the work of iron, the need of which was suggested by the increasing number of iron bridges. The system rests on the fact that a bar of iron, 1 metre long, stretches or shortens to the extent of one-tenth of a millimetre for a tension or compression of two kilogrammes per square metre of section. The apparatus requires great care in its use, and it should only be intrusted to conscientious and intelligent experimenters, but when such precautions are taken as are obviously necessary, it seems likely to yield valuable results. The experiments that are reported in the paper show a close accordance with theory. The theoretical maxima were never surpassed. C.

Removal of Grease from Feed-Water.—M. Hetet uses lime-water to fix the fatty acids in the feed-water of boilers in engines with surface condensers. The corrosive action of such acids rapidly wears out the boilers, and the greasy water cannot be made potable by distillation. M. Hetet's method has been introduced on many vessels of the French navy, and he claims that it adds greatly to the duration of the boilers, while it furnishes a distilled water without odor and without taste, and entirely unobjectionable for drinking or for cooking.—*Comptes Rendus.* C.

Condensation in Steam Cylinders.—In the *Ann. des Mines*, Pt. 3, for 1877, M. Ch. Ledoux discusses the condensation of vapor in the cylinders of steam engines. He claims that his method gives a sufficient practical approximation for each of the following estimates:

1. The weight of the mixture of steam and water furnished by the boiler at each stroke of the piston, the proportion of water carried over by the steam being known.

2. The proportion of suspended water, when the total weight of feed-water is known.

3. The consumption, in *calories*, for a given amount of work, or the true industrial measure of the utilization of steam.

4. In a locomotive, the quantity of water vaporized by the boiler during a given time, and the resulting power of traction at a given velocity. C.

St. Gothard Tunnel.—At the northern opening granitic beds have been encountered, and at the southern end abundant springs of water. These difficulties have been completely surmounted. The Italian journals anticipate the completion of the work by the spring of 1880, provided the necessary funds are raised.—*Les Mondes.*

C.

Book Notice.

The Telephone; an Account of the Phenomena of Electricity, Magnetism and Sound involved in its action. With directions for making a Speaking Telephone. By Prof. A. E. Dolbear. Lee & Shepard, Boston.

The intent of this little manual is set forth in its preface: "The popular exhibition of the speaking telephone during the past six months, together with numerous newspaper articles, have created a widespread interest in the instrument; and it has been thought that a small book, explanatory of its action, would meet a public want."

After a hasty, yet lucid, sketch of the discoveries in Electricity, Voltaic Electricity, Magnetism and Electro-magnetism, a chapter is devoted to the *theories* of electricity. The fundamental laws regulating sound are then explained. The "Correlation" of sound and electricity is demonstrated. The book concludes with a description of different telephones.

On describing the telephone of Prof. Bell, no other description is given than of one working by means of *electro-magnetism*. The recent improvement in Bell's telephone, of substituting permanent bar magnets for electro-magnets, is not referred to.

The author claims to have been the inventor of the speaking telephone "in which *magneto-electric* currents were utilized for the transmission of speech and other kinds of sound." If such a claim can be substantiated, the little manual does not make its appearance any too soon in contesting the association, by the public, of the name of Prof. Bell with the telephone, as claimed by the author.

We would recommend the book as a pleasantly written popular treatise on this "marvel in electric telegraphy." B.

Franklin Institute.

Hall of the Institute, Dec. 19th, 1877.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 119 members and 19 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 10 persons were elected members of the Institute, and the following donations were made to the Library:

Brief Inquiry into the principles, effects, etc., of the American Patent System. By H. & C. Howson, Phila. 4th Edition.

Illustrated account of the fire in the U. S. Patent Office Building, Sept. 24th, 1877. From H. & C. Howson, Phila.

Mahan's Industrial Drawing; comprising the description and uses of drawing instruments, etc. From J. Wiley & Sons.

List of writings relating to the method of least squares. By M. Merriman. From the Author.

Report of the Meteorological Committee of the Royal Society for seventeen months ending May 31st, 1877. From the Society.

Minutes of Proceedings of the Institution of Civil Engineers. Vol. 50. Session 1876–77. Part 4. London, 1877. From the Institution.

Polar Colonization. The preliminary Arctic expedition of 1877.

Annual report of the Secretary of War, for the fiscal year ending June 30th, 1877. Washington, 1877. From the Secretary.

State Agricultural College of Michigan, 1877, Twenty-first annual Catalogue of Officers, etc. From the College.

Report of the Superintendent of the U. S. Coast Survey, showing the progress of the survey during 1874. Washington, 1877. From the Superintendent.

Report of the Committee on Restoration of Independence Hall, 1873. From E. Hiltebrand.

A test for determining the position of a partial discontinuity without earth fault. By W. E. Ayrton and John Perry. From the Authors.

Annual report of the Surgeon-General, United States Army, 1877. From the Secretary of War.

Programm der Grossherzoglich Zadischen Polytechnischen Schule zu Carlsruhe fur 1877–78. From the School.

Memoirs of the Geological Survey of India. Vol. 13.
Palæontologia Indica. Ser. 2, 2. Jurassic flora of the Rajmahal Group. From the Survey.

Uber Oesterreichische Mastodonten und ihre beziehungen zu den Mastodonarten Europas, von M. Vacek. Wien 1877. From the K. K. Geol. Reïchsantstalt.

Report upon the U. S. Geographical Surveys west of the one hundredth meridian; Lieut. Wheeler in charge. Vol. 4, Palæontology. Washington, 1877. From the Chief of Engineers.

The Secretary presented his report, embracing Marcy's sciopticon, triple jet, and automatic cut-off; Hoyle's paper fastener and stamp; Chambers Bros. & Co.'s bolt and rivet clipper; and Norcross's governor for hot air furnaces.

On motion, the consideration of the amendments to the By-Laws, proposed at the last meeting, was postponed to the stated meeting in January next.

Mr. J. E. Mitchell offered the following, which was laid over under the rules:

Resolved, That the By-Laws be amended by striking out of Sec. 5, of Art. II, the words "on the payment of one dollar," and striking

out of Sec. 2, Art. I, the words "on payment of one dollar therefor."

The President announced that in accordance with Sec. 7, of Art. 14, of the By-Laws, the following nominations to be voted for at the annual election, to be held in January, 1878, should be made at this meeting:

A President, Secretary and Treasurer, to serve one year, one Vice-President, eight Managers, and one Auditor, to serve three years, and two Managers to serve one year, to fill vacancies.

The following members were then placed in nomination:

For President, Dr. R. E. Rogers.

For Vice-President, Chas. S. Close.

For Secretary, J. B. Knight.

For Treasurer, Frederick Fraley.

For Managers, Washington Jones, Pliny E. Chase, Jos. M. Wilson, Wm. P. Tatham, Dr. Isaac Norris, Jr., Theo. D. Rand, Coleman Sellers, Prof. Elihu Thomson, Wm. H. Thorne, Robt. Grimshaw, T. Morris Perot, C. H. Cramp, Geo. Burnham, M. Richards Mucklé, John McArthur, Jr., Wm. B. Bement, J. C. Trautwine, Jr., Mark Balderson, Jos. Newman, W. C. Allison, W. H. Burkhardt, A. W. Haines, Thos. Shaw, Dr. C. M. Cresson, G. M. Eldridge, John Hall, H. Howson, H. C. Lee, Geo. Doll, M. F. Bennerman, H. R. Heyl.

For Auditor, J. H. Cresson.

For Representative in Pennsylvania Museum and School of Industrial Art, J. B. Knight.

On motion it was

Resolved, That in the balloting for Managers, those receiving the eight highest numbers of votes, shall be declared elected for three years, and the two receiving the next highest numbers of votes, shall be declared elected for one year.

The President appointed the following members to act as tellers at the annual election, to be held on Jan. 16, 1878: W. A. Rollin, W. L. DuBois, Wm. Taggart, John Canby, Geo. Gardom, Saml. Sartain, G. M. Sandgran, J. W. Nystrom, Chas. Bullock, J. J. Weaver, W. P. Cooper.

On motion, the meeting adjourned.

J. B. Knight, *Secretary.*

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VOL. CV.] [NO. 626.

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VOL. CV. FEBRUARY, 1878. No. 2.

NEW PRINCIPLES OF HYDRAULICS.[1]

By LUIGI D'AURIA, Naval and Mech. Eng., etc.

I.—FUNDAMENTAL PRINCIPLES.

PROPOSITION I.—In any vessel or tube from which a liquid flows out, the flowing liquid (which we will call flowing vein) consists of a certain number of elementary liquid fillets, having origin upon the level surface of the liquid in the vessel or tube.

We indicate by A, a particle or molecule of a liquid which passes through a vessel or tube; and by B, the position of this molecule at a given instant, in a section Ω, of said liquid. In the following instant, for "continuity," another molecule, A', must occupy the position B of the molecule A; and for the same reason, at the same time, another molecule, A'', must occupy the position B' of the molecule A', etc. Continuing to reason in this manner, it will readily be seen that we will arrive at the level surface of liquid in

the vessel; and, therefore, we can conclude that the molecule A belongs to an elementary liquid fillet, $A, A', A'', A''', \ldots$, disposed on a certain line, $B, B', B'', B''', \ldots$, having origin on the said level surface. The same as for the molecule A, will be true for each molecule which passes through the section Ω; therefore, the proposed theorem is demonstrated.

Corollary.—The theory of the linear motion of fluids is inadmissible, because if we indicate, by $\delta\ \omega$, the section of one elementary liquid fillet, and by n, the number of fillets which constitute a given vein, through whatever vessel or pipe this vein passes, and whatever cross-section of this vessel or pipe we consider, the real section of the flowing liquid will be always

$$n\ \delta\ \omega = \omega;$$

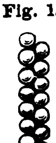
while this theory admits that, in a tube of variable section, the section of the flowing liquid is also variable.

(In future, ω will represent the real section of any flowing vein, and $\delta\ \omega$ that of a single fillet.)

Proposition II.—During the motion of a vein through a pipe of uniform section equal to ω, the principle of equal pressure, or Pascal's principle, cannot be verified; that is to say, if the vein is compressed in direction of its directrix, the compressing force does not produce bursting pressure in the pipe.

In fact, when a liquid at rest, contained in a vessel, is compressed, to transmit the compressing force upon the internal walls of this vessel, any of its molecules must push, "eccentrically," the others in direction of its real or virtual movement; that is to say, must act as a wedge upon them, and this fact cannot be verified in a vein which moves through a pipe of uniform section equal to ω, when it is compressed in direction of its directrix, being incompatible (Proposition I) with the disposition of its molecules.

Fig. 1.



Scholium.—Observing that the elementary liquid fillets which constitute the vein must be disposed as indicated in the annexed Fig. 1, that is to say, in such manner that one molecule of a fillet touches two molecules of each of the adjacent fillets (this being the only disposition compatible with the unalterability of density of the liquid), we see that, compressing the vein in direction perpendicular to its directrix (or in section), the

compressing force will be transmitted in direction of said directrix, at both parts of the compressed section of the vein.

Corollary I.—When a liquid passes from rest to motion, or *vice versa*, the disposition of its molecules changes. This fact could be of great interest in physics.

Corollary II.—During the motion of a vein through a pipe of uniform section equal to ω, the pressure experienced by this pipe arises only from the weight of the vein and from the centrifugal force of its molecules.

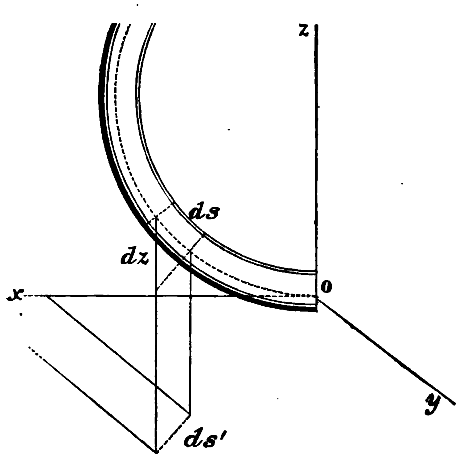
Important Remark.—All the molecules in every liquid fillet of a given vein, move with equal velocity; therefore, at each instant, the motive and resistant forces which act upon each one of them must be in equilibrium; and the same must be true of the motive and resistant forces which act upon every section of the vein.

II.—Equations concerning the Motion of Fluids.

Proposition I.—To find the pressure which is experienced by a pipe of uniform section, through which passes a flowing vein with uniform velocity, the section of the pipe being equal to ω.

Let $s = F(x, y, z)$, be the equation of the directrix of the pipe, Fig. 2, the lowest point of which is origin of the co-ordinates, and the axis z, vertical. Moreover, let u be the constant velocity of the vein; z, the vertical height of the pipe, and we suppose the whole weight of the vein uniformly concentrated on its directrix s, which we imagine divided into infinitesimal parts $d\,s$, each one of a weight $d\,q$. Let z and $z + d\,z$ be the vertical ordinates of the ends of an infinitesimal arch $d\,s$; and we decompose the weight $d\,q$ of this arch into two forces, one acting in direction of the tangent; the other in direction

Fig. 2.



of the normal considered in the vertical plane passing through ds; the latter will be

$$dN = \frac{ds'}{ds}dq,$$

ds' being the horizontal projection of ds. And observing that (when the specific weight of the liquid is unity) $dq = \omega\, ds$; substituting, we find

$$dN = \omega\, ds'.$$

Moreover, let ρ be the radius of curvature of the arch ds; and α the angle which it forms with dN; the centrifugal force of ds will be

$$\frac{ds\,.\,\omega}{g}\,.\,\frac{u^2}{\rho};$$

which, decomposed into two, one acting in the direction of dN (conspirant or non-conspirant with this force), and the other acting in a perpendicular direction, will give for the first,

$$\pm\frac{\omega\, u^2}{g}\,.\,\frac{ds\cos\alpha}{\rho};$$

and for the second,

$$\frac{\omega\, u^2}{g}\,.\,\frac{ds\sin\alpha}{\rho}.$$

Therefore, the pressures, experienced by the pipe in the considered section, are

$$\omega\left(ds' \pm \frac{u^2}{g}\,\frac{ds\cos\alpha}{\rho}\right),$$

acting in a vertical plane, and

$$\omega\frac{u^2}{g}\,.\,\frac{ds\sin\alpha}{\rho},$$

acting in a horizontal plane,

Integrating these two expressions between $z = o$, and $z = Z$, their sum will represent the total pressure P, experienced from the whole pipe, which pressure will be

$$p = \omega\left(s' \pm \frac{u^2}{g}\int\frac{ds\cos\alpha}{\rho} + \frac{u^2}{g}\int\frac{ds\sin\alpha}{\rho}\right);$$

s' represents the whole horizontal projection of the pipe.

PROPOSITION II.—To find the resistance to the flow of the preceding vein.

Indicating by f the coefficient of friction of the vein with the walls of the pipe, the frictional resistance will be

$$pf = \omega f\left(s' \pm \frac{u^2}{g}\int\frac{ds\cos\alpha}{\rho} + \frac{u^2}{g}\int\frac{ds\sin\alpha}{\rho}\right).$$

Indicating now, by θ, the force of adhesion of the liquid with the walls of the pipe (this force is independent of the pressure p), and by i, the ratio of the perimeter of the section of the pipe to the area of the same section, the total adhesion of the vein upon these walls will be $\omega i s \theta$; therefore, the total resistance to the flow of the vein will be

$$R = \omega\left[is\theta + f\left(s' \pm \frac{u^2}{g}\int\frac{ds\cos\alpha}{\rho} + \frac{u^2}{g}\int\frac{ds\sin\alpha}{\rho}\right)\right]. \quad (a)$$

PROPOSITION III.—To find the motive force which animates a section of a flowing vein, outside the orifice from which it disgorges.

Indicating, by h_1, h_2, h_3, ... h_n, the vertical heights of the n fillets of the vein which rest upon the section which we consider, the motive force of this section will be

$$P = \delta\,\omega\,(h_1 + h_2 + h_3 + \ldots + h_n);$$

or, multiplying and dividing for n,

$$P = \omega\,\frac{h_1 + h_2 + h_3 + \ldots + h_n}{n} = \omega\,h.$$

Considering also the resistance to the flow of the vein, will be

$$P = \omega\,h - R;$$

in which h represents the vertical distance of the centre of the considered section from the level surface.

Scholium.—When the vein moves with uniform velocity, we know, from mechanics, that this motive force must be equilibrated by a resistant force; consequently, the considered section experiences a pressure equal to the motive force

$$P = \omega\,h - R.$$

PROPOSITION IV.—To find the actual velocity of a flowing vein, which disgorges from a vessel of constant level surface and rises vertically.

Let h' be the vertical height of the liquid jet outside the orifice of the vessel (which jet we suppose of constant section ω). When the weight of this jet becomes equal to the motive force P, which

animates its lowest section, the velocity of the vein becomes uniform, and then will be

$$P = \omega h - R = \omega h',$$

from which

$$h' = h - \frac{R}{\omega}.$$

Otherwise, by law of the vertical rising of the bodies, the liquid, to rise at the height h', must have the initial velocity

$$u = \sqrt{2 g h'};$$

or

$$u = \sqrt{2 g \left(h - \frac{R}{\omega}\right)}. \quad . \quad . \quad . \quad . \quad . \quad . \quad (b)$$

When $R = 0$, we have

$$u = \sqrt{2 g h};$$

and in this consists the celebrated principle of Evangelista Torricelli.

Scholium.—Experience teaches us that the velocity of a flowing vein, which disgorges from the orifice of a vessel of constant level-surface, is uniform, whichever direction the liquid jet takes outside this vessel. Consequently (Proposition III, Chap. II), in any jet, the liquid section which occupies the area of the orifice of the vessel must be equilibrated. Now when a liquid jet is ascending, its own weight can equilibrate the motive force of this section; but if the jet is descending or horizontal, what resistant force equilibrates this motive force? Therefore, independently of gravity, we are compelled to admit an invisible resistance, which must act at least upon any descending or horizontal jet when it moves with uniform velocity. This new resistance takes place in the following manner:

The molecules of the flowing liquid, on leaving the orifice, independently of the general acceleration of the vein, receive a new acceleration which arises from their passage from the vessel to the air, where the resistance to the flow diminishes. Consequently, they attempt to separate from the vein, producing a vacuum. Then the atmospheric pressure becomes active, compresses the jet upon a more or less extended length (from which arises the *vena contracta*); and, as demonstrated (Prop'n II, Chap. I, Sch.), the compressing force P' of the jet is transmitted on one side, against the motive force P of the vein, and on the other, against the jet, dispersing it in the air. But the compressing atmospheric force P' increases with the accel-

eration of the vein; therefore, the movement becomes uniform only when

$$P' = P = h\,\omega - R.$$

Corollary.—The equations found in the preceding Proposition IV, as well as Torricelli's principle, are applicable to any jet.

(We observe that the distinguished disciple of Galileo had no right to generalize his principle.)

PROPOSITION V.—To find the actual velocity of a vein, which, from a vessel of constant level-surface, passes through a pipe of uniform section equal to ω.

In the equation (b), substituting, instead of R, its value (a); (neglecting the frictional resistance of the vein in the vessel as very small), we will have

$$u = \sqrt{2g\left[h - is\theta - f\left(s' \pm \frac{u^2}{g}\int\frac{ds\cos\alpha}{\rho} + \frac{u^2}{g}\int\frac{ds\sin\alpha}{\rho}\right)\right]}.$$

Squaring and resolving with reference to u, we will find

$$u = \sqrt{2g\,\frac{h - is\theta - fs'}{1 + 2f\left(\int\frac{ds\sin\alpha}{\rho} \pm \int\frac{ds\cos\alpha}{\rho}\right)}}.$$

If the vein moves on a vertical plane, $\alpha = o$, and

$$u = \sqrt{2g\,\frac{h - is\theta - fs'}{1 \pm 2f\int\frac{ds}{\rho}}};$$

and, if $\alpha = 90°$,

$$u = \sqrt{2g\,\frac{h - is\theta - fs'}{1 + 2f\int\frac{ds}{\rho}}}.$$

When a pipe is rectilinear and inclined, will be

$$u = \sqrt{2g\,(h - is\theta - fs')}, \quad \ldots \quad (c)$$

and, if vertical,

$$u = \sqrt{2g\,(h - is\theta)}. \quad \ldots \quad (d)$$

In practice, the water-conduits are formed of cylindrical pipes and circular bends, the inclination α of which is known. Therefore, if we represent, by c, the length of the directrix of a bend; by r its radius; the velocity u can be expressed in this manner:

$$u = \sqrt{2g\,\frac{h - is\theta - fs'}{1 + 2f\left(\Sigma\frac{c\sin\alpha}{r} \pm \Sigma\frac{c\cos\alpha}{r}\right)}};$$

an expression which can always be calculated with sufficient exactness, when the coefficients θ and f are known.

For determining the coefficient θ, it is sufficient to test the velocity u of a vein, through a cylindrical and vertical pipe of determined length, and substitute its value in the formula

$$\theta = \frac{2\,g\,h - u^2}{2\,g\,i\,s},$$

deduced from the equation (d).

When the coefficient θ is known, for determining the other, f, it is sufficient to test the velocity u of a vein through a cylindrical and inclined pipe of a determined length and inclination, and substitute its value in the formula

$$f = \frac{2\,g\,(h - i\,s\,\theta) - u^2}{2\,g\,s'},$$

deduced from the equation (c).

It is necessary to observe that the coefficients θ and f will be different for pipes of different materials.

III.—Theory of Water-Wheels.

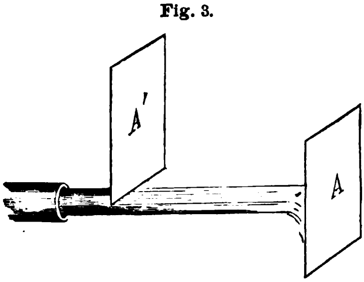
We have seen in the preceding chapter (Proposition III, Sch.), that the pressure experienced by a given section of a flowing vein, outside the orifice of the vessel from which it disgorges, is

$$P = \omega\,h - R = \omega\,\frac{u^2}{2\,g},$$

in which u represents the actual velocity of the vein.

Now if at the place of the given liquid section we imagine a plate which moves with the same velocity u of said section, this plate will experience also the same pressure P; therefore, if a plate is pushed by a flowing vein with relative velocity equal to zero, it will experience a pressure equal to the weight of a liquid column of the same density of the vein, having its base equal to the section ω of the vein, and its height equal that due to the velocity of said vein.

Fig. 3.



We imagine, now, a system of two thin plates A, A', thus (Fig. 3): that one, *i. e.*, A, enters perpendicularly in a flowing given vein, and moves, at the same time, par-

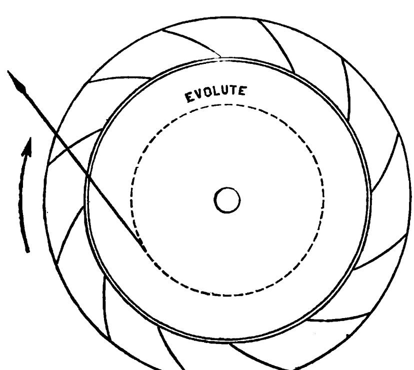
allel to itself, with the same velocity u of the vein. When it arrives at a certain point, it begins to come out from said vein, moving it always parallel to itself with velocity u. Then the other plate, A', enters in the same manner as the first, repeats the same movements, and, before coming out, re-enters the plate A, and so continually.

If we suppose the plates A, A', so thin that we may neglect the resistance which they encounter entering perpendicularly in the vein, it is clear that (without calculating any other passive resistance) the system above mentioned will give a useful effect,

$$L_u = \omega \frac{u^3}{2g},$$

and, from mechanics, we know that this is the maximum effect which a flowing vein can produce; that is, the absolute maximum useful effect of the system. Therefore, the question of the water-wheels is now merely a question of kinematics; because, if we find a wheel such that its buckets satisfy the same conditions as the system of plates, A, A', we shall always obtain the absolute maximum useful effect. This question we have fully resolved with our patented water-wheel, Fig. 4 (pat. 1877, U. S.), having its buckets of very thin plate, and curved as an arch of the involute of a circle concentrical to the axis of the said wheel. The propelling water acts upon them from inside to outside the wheel, in direction of the tangents to the evolute, and it is very easy to see the perfect identity of conditions between this wheel and the system of plates A, A', above described.

Fig. 4.



If the propelling water encounters the buckets with relative velocity greater than zero, the pressure upon them increases, but the velocity of the wheel diminishes. In this case the useful effect would be equal to the absolute maximum useful effect, but cannot be greater.

Our water-wheel can be disposed horizontally, as well as vertically. It is the practical expression of our theory, and the limit of perfection of any water-wheel.

ON THE RELATION OF MOISTURE IN AIR TO HEALTH AND COMFORT.[1]

By ROBT. BRIGGS, C. E., Cor. Mem. Am. Inst. of Architects, etc.

[Continued from Vol. lxxv, page 20.]

§ It is with some reluctance that I refer to the "Theory of Ventilation." The past eighty years have witnessed the growth of chemical science, which, after passing through numerous stages of development, as witnessed by the different nomenclatures, has finally reached the point, that only the chemists of continual study can comprehend it, and at which point he who knows most about it is the least satisfied with its present condition.

But thirty or forty years since, chemistry was supposed to have unlocked the mysteries of matter, and by the extension of the simple rules applicable to the gaseous and metallic elements, it was thought that the cause of disease or health was to be discovered. Careful observers then examined, from the chemical standpoint, the constitution of the air, both fresh and vitiated; and writers, with good logical conclusions, enunciated a *Theory*, by which is was made evident that chemistry had uncovered the root of disease, and carbonic acid gas was the fatal cause.

The real facts are these: An adult in still life inhales each minute about 480 cubic inches of fresh air, and exhales 488 cubic inches of vitiated air, of which vitiated air about 4 per cent. is carbonic acid, and from which about 19 per cent. of the oxygen originally supplied by the fresh air has been abstracted; the original quantity of vapor in the fresh air at mean temperature and hygrometric condition (62° and 65 per cent.) will have been increased from 1·1 to 3·08 grains.

Carbonic acid gas was made the scapegoat. It killed dogs at the Grotto del Cane, as was happily exhibited to numerous travelers in Italy at that time—and both before and since, the same unfortunate dog serving to be killed, to the satisfaction of admirers, that had been resuscitated the day before, after the visitors' backs were turned. It was heavier than air, and in some conditions of temperature would not so readily diffuse, but form a layer of distinct gas, like water beneath oil. Altogether it answered the conditions of hypotheses,

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[1] Paper read before the Am. Institute of Architects, at Boston, Oct. 18th, 1877.

and it was decided to be vile, deleterious, poisonous. To be sure, we devoured it in bread and drank it in beer, or aerated waters, but then the poison was to the lungs, not to the stomach! This theory found promulgators in the lecture rooms, and advocates in the household thirty years ago, and has become to-day the *traditional* belief of the middle aged and elderly. If a room is hot or close from excess of temperature, or from a crowd of occupants, carbonic acid gas is the difficulty; if malaria is developed in a jail or hospital, or typhus or scarlet fever exist in the dwelling, carbonic acid gas in excess is the poison. "The gas is heavier than air, and must necessarily sink to the floor, where all the air of vitiation will be found." These notions continue to have advocates and supporters to the present time, and the popular lecturer or writer gives a half assent to them, to secure the favorable opinion of audiences or readers. But step by step, during the past thirty years, it has come to be perceived that the causes of disease are not to be found with inorganic matter, and carbonic acid has been removed from its elevated place in ventilation, with the fullest admissions, that in the quantities ever present in the living rooms, except by accident, it is quite harmless; and finally, its presence has been accepted as merely a measure of other more dangerous vitiations, in that as it is a definite product of respiration, and as the proportion present in any room, at a given moment, can be ascertained with tolerable exactness, an indication can be derived thereby of the extent of organic vitiation with some degree of certainty.

The unquestioned theory of malaria, the meaning of which word can be extended to embrace diseases arising from deficient or defective ventilation, to-day, is organic vitiation, and the probability of this theory holding its place in future, is, I think, a very fair one. The exhaled and exuded vapor from the human body is known to be laden with organic matter; much of this organic matter is within the range of the microscope, by means of which the local derivation of many particles can be determined; but some of it is in the form of effluvia and odors, which pass the limits of visual observation in the smallness of the atoms, notwithstanding such effluvia or odors are decidedly perceptible to the sense of smell. With a dry external atmosphere and a reasonably free ventilation, the exuded vapor and the organic matter pass away, or are diffused as rapidly as supplied. *It should be remarked that the organic matter appears mainly to be in connection with the vapor in the air, and not to exist*

as a separate gas, diffused in the dry air when the vapor is removed by natural causes. With an imperfect or insufficient ventilation, the upper parts of rooms become filled with air, which will be found to contain a much larger proportion of moisture than the lower portions, and will be shortly found to be exceedingly offensive from the rapid decomposition which the exuded organic matter undergoes in a moist air. This will happen more frequently when the internal and external temperatures are about the same, and when it is so cold, raw, or windy, as to require closed doors and windows, with only a small addition of heat, and when with these conditions the natural dew point is high. These circumstances are in concurrence frequently in England, where probably 120 days out of 365 call for but small addition of heat in rooms, while they rarely exist with us; the climate of our northern United State not giving 30 days in any year of similar kind. The objection of *effluvia*, which forms the distinctive one in audience rooms in England, and is so noticeable to the American visitor of such rooms, is replaced in our halls by a simple sense of oppression—a mere feeling of discomfort—which, on the other hand, is particularly noticeable to the English visitor of our halls, who is apt to associate it with a supposed excess of heat.

But this organic matter of exhalation is still one step removed from malaria, it is only the ground of malaria—the soil on which a malarial growth will propagate; its *decomposition* is held to supply the means of fecundity to the germs of disease. In the warm air confined in the upper parts of rooms, with excess of moisture, it may undergo a rapid and somewhat fetid decomposition; under such circumstances it is found to become offensive in six to ten minutes. With a smaller proportion of moisture, or when it is rapidly absorbed with the moisture by diffusion into air of American dryness, it does not decompose so rapidly, but is likely to be absorbed by any hygroscopic substance the air containing it may come in contact with. The walls of rooms, especially the porous plastering, stone or bricks, and possibly the papered and painted walls, will take up the excess of moisture with its organisms, and give up at another time, wholly or in part, the moisture without them. There is a characteristic smell of walls of kitchens, cabinets, hospitals, jails, court rooms, and similar permanently occupied places, which can be developed in intensity by simply holding the half closed warm hand against the face of the wall, and testing the result by the sense of smell of the hand. In

such instances of retention of the results of imperfect ventilation, the eventual propagation of disease is a certain one.

To the vegetable and lower animal growth, the presence of moisture in the air seems a positive necessity; where it is absent they perish, or at least no longer grow or propagate. The drinking animal apparently suffers the least of injury, and but little discomfort in the dryness of the air of whatever temperature. The immunity from disease to the human race which accompanies the dryer regions of the earth, has been frequently remarked, and the fact meets general assent. The discomfort of the colder countries, even to the limits of the arctic regions, is one of cold, not of absence of moisture. The assertion of relative insensibility to cold air devoid of moisture, is the common report of all travelers in such regions; while the dreaded malarial diseases of more genial lands do not exist in them at all. In the temperate zone, in countries or localities which possess the dryest of atmospheres, with the least variation of hygrometric condition, mankind is most free from disease of all descriptions. The elevated dry and barren lands of our midland country, from Minnesota southwardly, are the healthiest regions of the United States; and where, together with the *dry* atmosphere, some uniformity of temperature exists, as in Mexico—where the height above the level of the sea reduces the sensible heat of the air, which is usually found in that latitude, to a comfortable one—there we have the acknowledged climate of utmost healthfulness. Going into more torrid lands, the dryness of the air alleviates the heat of the deserts of Arabia, and of Africa, of Peru and Bolivia, where the temperature rises at times to 110° or even 120° in the shade. I have the assertion of a friend that on a hot day, with the thermometer nearly 100°, he has known the wind on the Arabian desert to be searchingly cold, when everything was shriveling up for want of moisture. My attention was called by Dr. J. S. Billings to the following extract of his report on the Hygiene of the U. S. Army in 1875:—"Description of military posts, Fort Yuma, California. Reports of Asst. Surgeons Lauderdale and Ross, U. S. A. After describing the locality of the post, near the junction of the Giler and Colorado Rivers, they say: * * * 'The heat increases rapidly from the latter part of May, and in June, July, August and September may be said to be intense * * During the months of April, May and June no rain falls; then, with the thermometer at 105°, the perspiration is scarcely seen upon the skin,

and it becomes dry and hard, and the hair crispy, and furniture falls to pieces, * * ink dries so rapidly upon the pen that it requires washing off every few minutes. * * A No. 2 Faber's pencil leaves no more trace on paper than a piece of anthracite, and it is necessary to keep one immersed in water while using one that has been standing in water some time. Newspapers require to be handled with care, if rudely handled they break. Twelve pound boxes of soap, when reweighed, gave but ten pounds. Hams had lost 12 per cent. and rice 2 per cent. of original weight. Eggs that had been on hand for a few weeks lose their watery contents by evaporation, the remainder is tough and hard; this has probably led to the story that our hens lay hard boiled eggs.

"'The mercury gained its highest point last summer on the 2d day of July, when for two hours it stood at 113° in the shade. All metallic bodies were hot to the touch, my watch felt like a hot boiled egg in my pocket * * *

"'This post, although not the most southerly, is the hottest military post in the United States; the highest temperature recorded on our books since 1850, when the post was established, is 119°, observed at 2.25 P. M., June 16th, 1859. A temperature of 100° may exist at Fort Yuma for weeks in succession and there will be no additional cases of sickness in consequence * * * We have none of the malarial diseases * * No ice is formed at any time; 29° has been indicated by a registering thermometer in January, 1872. The mean temperature, day and night, of January, however, is 57°; that of July is 95°. The average rainfall during four years was a little over 2 inches each year.'"

Any who wish to corroborate or question these views as to the healthiness or unhealthiness of dry air, hot or cold, can examine authorities, or investigate or observe for themselves; the conclusions they will reach can be confidently anticipated. But the proof or argument cannot be further extended in this paper, and it must be claimed that there exist good grounds to believe that dry air, *per se*, of whatever temperature it may be found on the surface of the earth, is not unhealthy; that, as regards disease, such air possesses both preventive and curative qualities of great value; and that, on the other hand, moist air, such as promotes vegetable growth, is not desirable for breathing on sanitary grounds. Asserting these views, the question narrows down to: given a habitat or place of residence, where some

degree of moisture and vegetation does thrive for a portion of the year, at least—what effect on the system do the variations of moisture produce, from season to season, from day to day, and during such of the seasons as the comfort of inhabitants may call for artificial warmth, from one place to another on the same day?

§ Clothing, houses and fires are the means by which mankind is enabled to inhabit the face of the earth. It is an artificial existence for an animal whose natural life would otherwise be limited to a small belt of the torrid zone, where the temperature never falls below about 80°, nor rises above 100°. As residents of the northern United States, we cannot expect to avoid, and do not expect to ameliorate, the vicissitudes of climate *out of doors*. Hot or cold, rainy or dry, with air relatively humid or otherwise, life in all countries means endurance under artificial guards or protections from natural inclemencies. We clothe ourselves by the umbrella on the one hand, or the great coat on the other; open or close our doors; induce cool breezes, or gather around fires, in search of the *comfortable uniform* loss of heat by the system. The efforts to accomplish this end, by means of change of temperature or relative moisture of the air, are of necessity confined to the cold, or at least cool, season, with infrequent attempts to obtain an artificial degree of cold in extreme hot weather. In moderate weather, the vicissitudes of temperature, and of humid condition of the air, are endured with the expression of discomfort and the tacit admission, on all hands, that our great day-by-day variations of the mild season are harmful to the feeble or sickly. But these daily changes of temperature and of hygrometric condition are of small account with those which in the Northern states accompany the season of cold. The change of climate from that which accompanies, during any of the winter months, our warm south winds, to that which accompanies a great northwestern wind wave which may follow the southerly breeze within twelve hours; a change from 50° to 60°, with 80 per cent. saturation, to even below zero, with an unascertainable dew point: such a change is trying to the extreme. The prevalent disease of the land is consumption of the lungs, and these changes are disastrous to those who are suffering from this complaint; and, to the healthy, these changes are held to be fraught with danger.

§ A very simple and commonplace observation will make the general condition of air in rooms in winter, as regards humidity, the subject

of positive demonstration. During the season of winter in our climate, after a continued spell of cold weather, the exhibition of condensed moisture or of frost on the window panes is very unfrequent. The usual provision of glass in windows throughout the northern United States, is in single thickness, not double plates; the latter arrangement being decidedly exceptional as a means of preventing transfer and loss of heat at the windows. The temperature of a pane of glass which is interposed between two temperatures of still air, that is of air devoid of currents, except those generated by the differences of temperatures of the air on either side, and the glass, is obviously that of a mean between the said two temperatures of air. With so good a conductor as glass, and with plates as thin as ordinary window glass, the conductivity of the glass may be assumed to be perfect, and both sides of a pane can be deemed to have the same mean temperature. But the temperature of the air on each side of a pane differs from either that of the external air on the one side, or of the room on the other. On the outside, the layer of cold air in contact with the pane ascends slowly as it is heated, and the vacuity which is formed at the bottom of a pane is supplied by fresh cold air, so that the layer at this point approximates to the temperature of the outer air closely. On the inside, the layer of warm air in contact with the pane descends as it is cooled, having, perhaps, an approximation to the inside temperature at the top of the pane, but by the time the layer has flown downwards to the bottom of the pane, its temperature will have become materially lower than that of air of the room generally. So that while the law of mean temperature of the pane at the bottom of the pane is yet good, the real temperature may be much lower than a simple mean between thermometers hung in the room and out of doors. Beside the supposition of still air, much allowance must be made for the effect of winter winds in accelerating the flow of cold air on the outside of the pane until the outer layer is very nearly of uniform coldness, which favors the greater abstraction of heat from the internal descending current, and cools down the lower part of the pane still further. Curtains, shades or internal blinds, while they aid in protecting the room from loss of heat, also protect the glass from acquiring the temperature due to the heat of the room. Until with the supposed case of external air at 10° above zero, and a moderate wind out of doors, and of a room warmed to 75° inside, the

temperature of the panes near the bottom, or even well up their height, will be much below 42½° as the mean; and 27° to 28° may fairly be taken as giving the real temperature near the bottom. This pane of glass becomes then a dew point thermometer at all times in the winter, ready for indicating the humidity in the air. Except, however, a crowd of people, or some artificial "hydration" carried possibly to momentary excess under the stimulus of the last theorizer, or a very new house, or a damp cellar in an old one, we but rarely see any indication of presence of moisture in our dwellings in cold weather. This simple test will show that our dwellings, although the water troughs of the hot air furnaces do supply limited quantities of vapor with admitted comfort, do not, as a rule, have over 30 to 40 per cent. of humidity in the air within them.

The entire range of our Atlantic coast is only removed from a region of perpetual spring from 200 to 500 miles; and a southeast wind, from December to April, may bring a vapor laden air, which, in a few hours, will have changed our frigid winter to a genial spring. The succeeding wave of northwest winds—a great current which the Signal Service has traced up to the Arctic regions—may, with great violence, restore the winter with all its rigor, within another few hours. Under this change, heavily frosted windows become the rule, and they indicate a dew point above the temperature of the panes of glass, at once. So dry and arid are these winds, however, that with the continuance of a northwest wind for a single day, all traces of window frosting will have disappeared.

This test of the dew point by the window, is very accurate. As an instance, I will quote that on one day in this present month, in Philadelphia, with the thermometer in-doors at 64°, without fire, a fall of temperature to 54° outside, produced immediate condensation on windows, showing 75° to 80° of humidity. Now if a difference of only 10° produces this indication for *humid* air, the want of such an indication with difference of up to 65°, must manifestly be a very dry air. By actual trial in well warmed and ventilated rooms, the writer has found the dew point far below the freezing point of water, in rooms where the sensation of dryness, which is held to accompany the heat of the furnace when not supplied with water for evaporation, certainly did not exist.

It is proper when alluding to the dampness of houses, to advert to one of the most striking differences between England and western

Europe, and the northern United States, in the necessities which climate imposes in the relation of humidity in air to the health, in this particular regard. We find all foreign authors speaking in unequivocal language of the great danger of inhabiting a newly built and consequently imperfectly dried house. One English writer, whose name I cannot recall, but I remember to have been of much eminence, asserted that no house ought to be occupied until a year after completion. Many writers on ventilation join in estimating by figures the quantity of moisture in the new walls, and *demonstrate* the dangers of a residence, where the excess of moisture in the air, the want of permeability of the walls, and the increase of conductivity of heat through the damp walls, will have produced such a tomb-like house. While in America we are fully alive to the danger in the house, from air overladen with moisture, as from a damp cellar, or location in a damp place or vicinity, and appreciate that rheumatism and consumption, with scarlet fever for the children in winter, when the house is thoroughly warmed, and typhus for adults in mild weather, are the possible, if not probable, penalties for living in such a house; yet the new house, from its inherent dampness, only is considered at least as but objectionable in a small degree. Except that dampness exists from other sources than that which comes from the walls, our new houses are quite as healthy during the first year, or the first season's occupation, as afterwards. No preliminary drying out is needed as a rule. Our summers or winters are dry enough to take up all the moisture which walls may give, without overlading the air with humidity; although it is noticeable, that new houses require more fuel to warm them the first winter than afterwards, as the supply of heat must be sufficient to evaporate an excess of moisture, and the conductivity of the walls is somewhat greater before they are thoroughly dried out. Few dwellings are completed for occupancy at the end of winter or of summer—residence generally begins with the beginning of summer or of winter, and the seasons when the dampness of walls would be dangerous from the existence of a humid air are not those when new houses are generally first occupied.

§ Although not directly related to the subject, I will mention here one curious demonstration of the effect of atmospheric humidity and impurity which is peculiar and common in England. All American readers, or observers, become aware of the great importance attached by the English public, as a people, as writers, and as a government, to the

relative purity of illuminating gas, but it is not generally known, or even asserted, that the cause in England which makes the impurities of gas obvious, and renders them seriously objectionable, is to be found in the air of the room, and not alone or even mainly in the gas itself. The sense of oppression from the burning of gas in dwellings in England, is one that can be appreciated only by being felt; any description fails to convey to the mind of the untraveled American, the burden on the breathing functions which results from gas burning in a humid and impure air. It is enough to say that throughout England, gas lighting is regarded as only suitable for shops, workrooms, warehouses, public rooms and such other places, within or without of doors, as demand light for passengers, rather than for occupants. When halls are lighted by gas, the chandeliers (gasoliers is the English word) and bracket lights are not considered to be well arranged unless "ventilated;" in other words, provided with especial means—air passages or outlets—for removal of the gases of combustion, with the accompaniment of a volume of heated air. The dwellings—dining and drawing rooms, passages, and chambers—of the more wealthy, are lighted nearly universally by candles of wax, sperm, or some prepared fatty substance, either animal, vegetable or mineral, with the occasional or frequent use of the carcel-lamp as a table light. From any English gas light there arises a current of impurities which in a brief space of time discolors, and coats with black, the interior of the ventilating tubes, or, in absence of such protectors, the canopies of glass or metal which are usually supplied for unventilated burners; or when this last protection is wanting, the ceiling, even when several feet above the burner, is quickly marked by a halo of greasy soot, which adheres to it where the ascending current impinges.

The heat emanating from a gas burner, as compared to that from a number of candles giving the same amount of light, is very nearly the same, about seven per cent. more heat being given out by the candles; but the 14 to 16 candles, which represent the single gas burner, will have been dispersed about a room, or even when grouped in threes or sevens, as usual in sconces, candelabra or chandeliers, will be spread widely asunder, so that the current proceeding upwards from each separate candle will have become diffused before reaching the ceiling; and, if the candles give out the same impurities (which they do not) as the gas burners, the obvious impurities which make a mark will not be precipitated to show themselves as spots. Besides

this, a room lighted by candles will be considered brilliantly illuminated by three or four candles, where one gas burner would have been used; so that one-fourth the quantity of light will be made to suffice with candle illumination, to what is requisite for gas lighting. The numerous candles come in proximity to the objects to be lighted, while the gas burner, with its volume of light and of heat, must be further removed to be tolerable; and there is an actual requirement for more light from the latter than the former source to give the same effect in the room. The other substitute for the gas burner, the carcel-lamp, is frequently used in England as the centre-piece, singly or in numbers, of the tables in the dining room, drawing room, or library. Its illuminating power is about two-thirds that of a gas burner, and the quantity of heat given out bears very nearly the same relation, that is, the heat from a carcel-lamp is about two-thirds that from a single gas burner of 14 to 16 candle power. As the carcel-lamp is movable in a room, and is usually placed low down, the chance of the current of air proceeding from it defacing the ceiling, is much less than from a fixed gas burner, in its usual position of height from the floor.

What may be the exact physical or chemical conditions accompanying the manifestation of *bad* gas in England might call for a long discussion in reply. It can be said at once that the indications on the ceilings are almost entirely those of atmospheric impurities and condensation of water. Soot, dust and organic matter in suspension in a saturated humid air—wherein the humidity is the vehicle which carries these substances, and is not free to disperse them from the general saturation—will be and are deposited on the first object of cooling and contact. This view of the case is not a mere guess. The fact that there is a general discoloration of ceilings from gas burners in England, as contrasted with those of the continent, where the air is uniformly a little more dry, and where the use of bituminous coal is unknown, so that its particles of carbon dust do not form a part of the common impurities of the air; and also as contrasted with the ceilings in this country; this fact is certain, and from it the connection of pure air with the *cleanliness* of gas burning is made evident. While English gas is much more carefully purified and treated than any in the world, the standard of its excellence is not only the highest, but it is made strictly up to this standard. Yet any sulphurous or sulphuric acids which emanate from gas lights, are at

once absorbed by the vapor present, and if the atmospheric condition does not facilitate the diffusion of this vapor, these acids are retained in the ascending column to exert their energies on the objects of first contact, and afterwards retained in the room to act generally on any sulphur absorbent, colors or materials, as they do in England and do not in this country. It is probable in our climate, and in that of the continent, much of the humidity of combustion, and of the deleterious gases either evolved by, or inherent to, the illuminating gas—as well as the organic impurities, dust or soot, in the air burnt or heated by the act of burning—is diffused at once into the tenuious vapor of the surrounding air. Not only before passing four or five feet from the burner, so that no condensation takes place on the ceiling, but also so thoroughly diffused as to prevent, in great degree, those chemical actions which prove so objectionable from the burning of the best purified coal gas in England.

[To be continued.]

THE STRENGTH AND DUCTILITY OF IRON AND STEEL BOILER PLATE, AT DIFFERENT TEMPERATURES.

By CHARLES HUSTON.

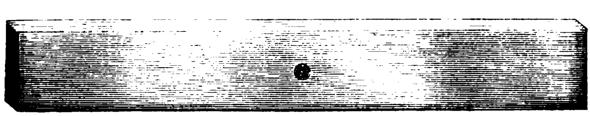
The present law of Congress requires all makers of boiler plate for marine boilers, to stamp on their iron the number of pounds tensile strength it will sustain before breaking, making it obligatory on the inspectors of the several districts to see that the plates shall possess the strength stamped upon them, and also that they shall have the other qualities required by law, viz., homogeneousness, toughness, and ability to withstand the effect of repeated heating and cooling.

This, as will be seen, covers a *very large field*, and requires much experience and skill, on the part of the local inspector, in all the qualities of iron or steel that may be used in the construction of boilers; the mere question of tensile strength may not be very difficult to ascertain, but the question of "*homogeneousness, toughness, and ability to withstand the effect of repeated heating and cooling,*" is a very different one, and involves a large degree of knowledge in

matters still in more or less doubt with the most eminent scientists of the day.

In order, therefore, to settle in my own mind, by practical tests, some of these questions, I have been led to make the following experiments, to ascertain the comparative strength and toughness of four different samples of boiler plate: 1, cold; 2, at 300° C. (572° Fahr.); and 3, at 500° C. (932° Fahr.); taking as my measure of *toughness* the degree of contraction of area at the point of fracture. I have taken nine pieces, each from the same plate: 1, *charcoal boiler plate*, made from the pile in the ordinary way; 2, a very exceptionally soft piece of Siemens-Martin steel; 3, a piece of ordinarily soft crucible steel, such as is generally used for boilers, and will not harden when heated and plunged into water; and 4, a rather harder piece of crucible steel, that will become more rigid when heated and plunged into water, but still soft enough to bend flat without breaking. Making three tests at the same temperature, enables us to form an approximate idea of the *homogeneousness* of each kind of plate, both as to tensile strength, and also as to toughness; but it will, of course, require a large number of tests to establish the correctness, or otherwise, of those I now have the pleasure of giving you.

The most troublesome question I had to contend with, was the best way to measure the temperature of the test-piece and maintain it, while the test was being made, but finally I adopted the following: I made the breaking point in the test-piece by taking a piece of the plate planed with parallel sides, about one inch wide, and in the middle drilled a hole about $\frac{2}{10}$ of an inch in diameter, thus,



thereby reducing the area of the test-piece at that as a breaking point. This hole I then filled with a plug of amalgam of known melting point—for 300° C. I used an amalgam of 32·3 tin and 67·7 lead, and for 500° C. I used an amalgam of 75·5 lead and 24·5 silver (see "Die Metallurgie, John Percy, übertragen und bearbeitet von Dr. F. Knapp und Dr. H. Wedding"). Having thus prepared the test-piece, it was fixed in the testing machine, and a full, large flame of a blowpipe, covering the whole width of the test-piece, was applied. As soon as the amalgam became *semi-solid* on the side opposite to

that on which the flame was directed, I kept it in that state while my assistants carried the strain up to the point of rupture.

1.—Charcoal Boiler Plate, Piled.

Tensile Strength.

	Cold.	300° Centigrade.	500° Centigrade.
	56,500	66,940	70,130
	52,300	59,300	62,800
	57,300	63,000	63,100
Average,	55,366	63,080	65,343
Percentage of gain,		13·93	18·02

Contraction of Area (Percentage).

	Cold.	300° Centigrade.	500° Centigrade.
	28	23.5	22
	26	22.5	21
	24	23.5	21
Average,	26	23·17	21·33
Percentage of loss,		10·88	17·69

2.—Siemens-Martin (Exceptionally Soft).

Tensile Strength.

	Cold.	300° Centigrade.	500° Centigrade.
	51,400	66,700	61,700
	55,800	66,350	64,250
	56,600	65,200	67,100
Average,	54,600	66,083	64,350
Percentage of gain,		21·03	17·86

Contraction of Area (Percentage).

	Cold.	300° Centigrade.	500° Centigrade.
	50	40	32
	50	41	36
	41	32	32·5
Average,	47	37·66	33·5
Percentage of loss,		19·85	28·72

3.—Crucible Steel (Ordinarily Soft).

Tensile Strength.

	Cold.	300° Centigrade.	500° Centigrade.
	61,600	66,800	65,400
	68,000	68,600	69,600
	62,400	72,400	70,800
Average,	64,000	69,266	68,600
Percentage of gain, . . .		8·23	7·18

Contraction of Area (Percentage).

	Cold.	300° Centigrade.	500° Centigrade.
	37	37	21
	35	29	22
	37	24	21
Average,	36·33	30	21·33
Percentage of loss, . . .		17·42	41·29

4.—Crucible Steel (Not Quite Hard Enough to Temper).

Tensile Strength.

	Cold.	300° Centigrade.	500° Centigrade.
	77,900	79,500	81,700
	77,800	87,800	82,000
	79,400	81,000	68,000
Average,	78,366	82,766	77,266
Percentage of gain, . .		5.62	
Percentage of loss, ...			1·4

Contraction of Area (Percentage).

	Cold.	300° Centigrade.	500° Centigrade.
	28	13·25	16·25
	28	23·	22·
	24	12·	22·
Average,	26·66	16.08	20·08
Percentage of loss, . .		39·69	24·68

The result of these few experiments would seem to show that in all the four samples of boiler plate there was a decided increase of tensile strength at 300° C., and a still continued increase at 500° C., in the charcoal piled iron, but a falling off at 500° C. in the Siemens-Martin and crucible steel in proportion to the probable amount of

carbon, in the case of No. 4 bringing the strength a little below that at the ordinary temperature.

In the contraction of area representing the *ductility* of the metal, there is a constant *decrease* the larger the percentage of carbon (as indicated by the degree of hardness), the greater the loss of ductility, except in the case of No. 4, which, from some cause, shows great irregularity when heated, averaging more at 500° C. than at 300° C.

These experiments are necessarily delicate, and require great care to avoid error in measuring the degree of heat as well as in the measurement of the test-pieces before and after being pulled. I have taken all the pains I could, and hope some more able, better qualified individual may pursue the investigation further, and either confirm or disprove what I have stated. If, however, the foregoing tests are correct, it becomes a serious question as to the practice of making steel boilers any thinner than those made from iron.

LUKENS' ROLLING MILL, *Coatesville, Pa., Jan. 10th*, 1878.

THE SEYSS AUTOMATIC WEIGHING AND SORTING MACHINE FOR COIN.

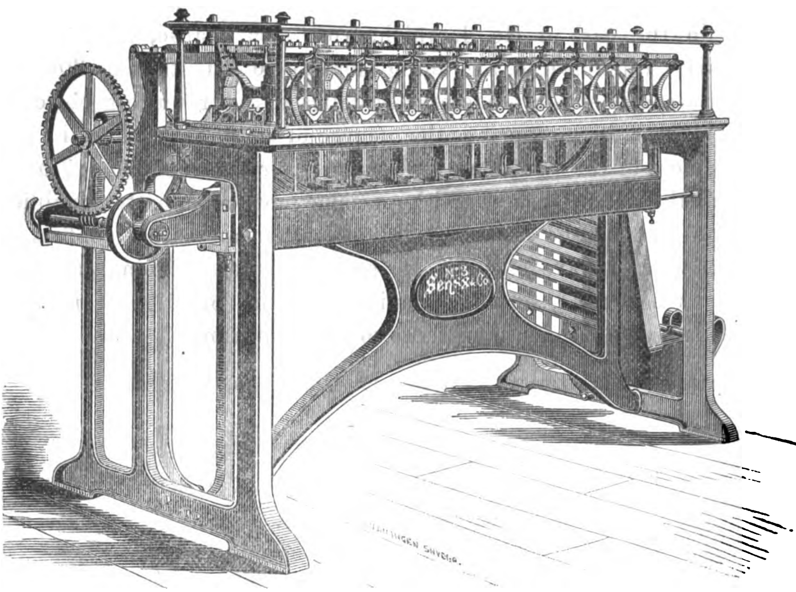
By SAMUEL JAMES.

This machine was designed and first built by Mr. Ludwig Seyss, at the request of the Master of the Imperial and Royal Mint in Vienna, who was desirous of obtaining a reliable automatic balance for the purpose of sorting the planchets used for coinage, into three separate classes, namely, those that were of the standard weight, those that were lighter, and those that were heavier than the standard. This classification was afterwards enlarged so that the machine was able to divide the heavy planchets into three separate classes, making the scraping or filing of the planchets to the standard weight of much more convenience.

All the working parts of the machine are supported on a frame of cast iron, as will be seen by Fig. 1. The power necessary to operate the machine, which has been estimated to be the one-tenth part of a horse power, is derived from any motor of a uniform and reliable motion, which motion is transmitted to the machine by the

means of a cord belt passing over the pulley on the shaft at the end of the machine, giving to the shaft a speed of 160 revolutions per minute. Upon this shaft is placed a worm, which gears into a wheel

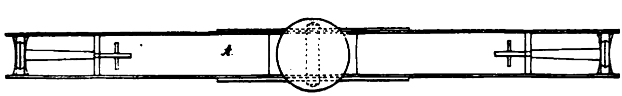
Fig. 1.



upon the end of a shaft running in front of, and parallel with, the machine. The motion is, therefore, transmitted to this shaft, which has upon either end three cams, which, by the revolution of the shaft, transmit the motion to the other parts of the machine.

The construction of the balance is as follows: The beam, Fig. 2, is made of two thin plates of silver-plated steel, held together by suit-

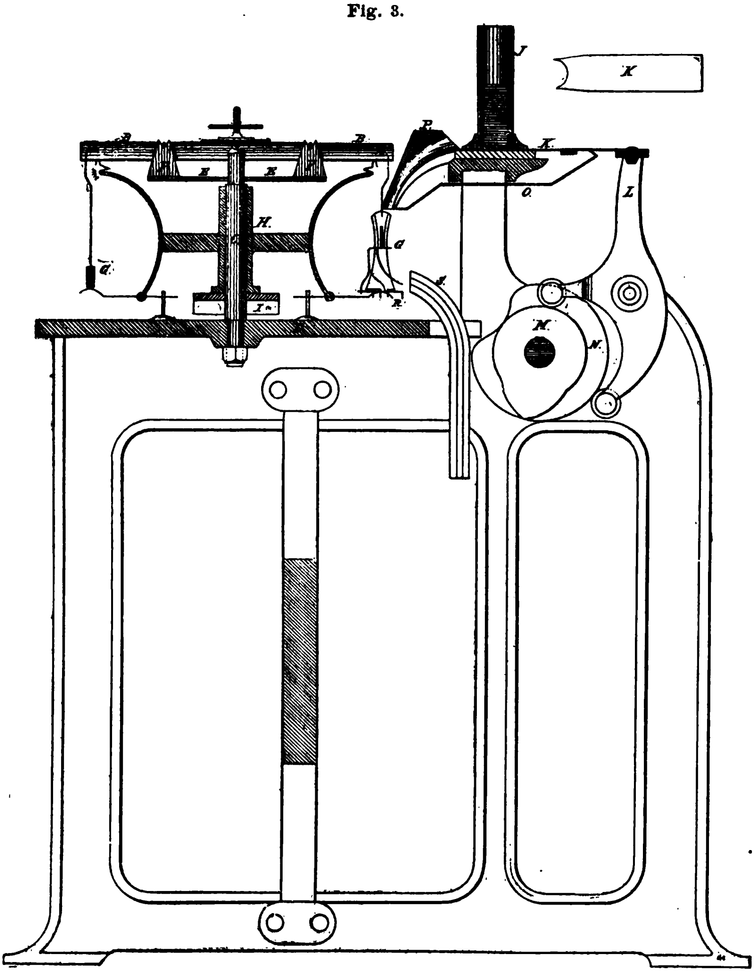
Fig. 2.



able pins or supports, and is 30 centimetres long between the knife edges; the weight of the beam being 86 grammes, and each basket or pan 32·7 grammes, making the total weight of the beam and baskets 151·4 grammes. *GG*, Fig. 3, are the baskets, or pans, suspended at either end of the beam. The one at the right carries the planchet to be weighed, and the one at the left carries the weight to which it

should correspond. The centre knife edge rests upon an agate bed, and the baskets or pans are hung by agate bearings, on knife edges, at either end of the beam. The beam is readily adjusted by means of a small brass nut, which runs upon a screw fastened between, and parallel with, the steel plates of the beam; the sensitiveness of

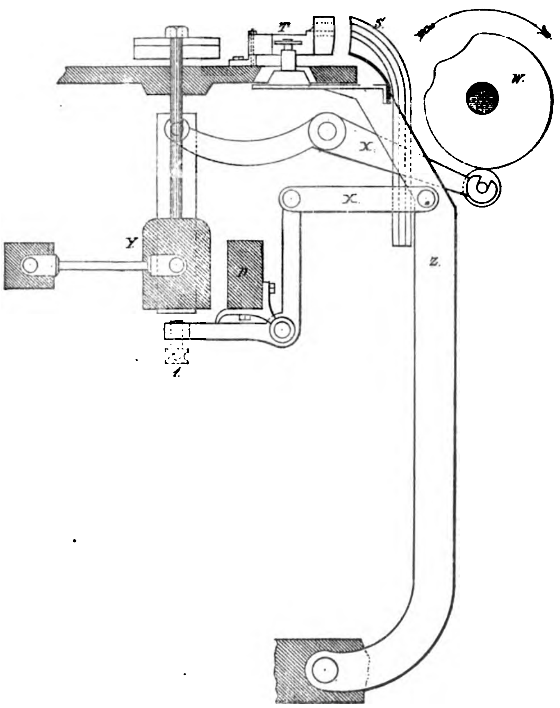
Fig. 3.



the beam being adjusted by a brass nut running upon a screw fastened in a vertical position over the centre knife edge. The balances, ten in number, are arranged upon a cast iron plate or table, supported at either end by the frame of the machine. Each balance rests by its centre knife edge upon a column, *C*, Fig. 3, screwed fast into the bed-

plate or table, *D*, and having horizontal arms upon its upper end. The horizontal arms support, at their ends, rests of thin steel cut V-shaped at their upper extremities, for the purpose of holding the small gold wire riders, used to mark the light and heavy allowance. Upon this column which supports the beam, is a sliding cylinder of brass, *H*, with arms extending from it, for the purpose of arresting and quieting the beam and baskets. This is done by the means of a light spring of sheet brass upon the upper end of each arm, which touches lightly under either end of the beam, and by fingers jointed into the lower end of the arms. These fingers touch lightly under the basket with one end, while the other end slides with a slight friction over a pin fastened in a vertical position in the bed or table. This brass cylinder is fastened to a flat iron bar, *I*, which extends the whole length of the table, and is supported by three iron stems, resting upon the weight, *Y*, Fig. 4, suspended below.

Fig. 4.



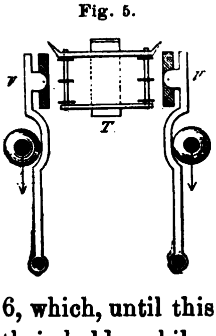
In front of the table upon which the balances are arranged, and supported by the frame at either end, is a plate, upon which are arranged the tubes or vertical cylinders of brass, *J*, Fig. 3, used to receive and hold the planchets, before being passed to the balances, and also the boxes, or compartments, *P*, into which each planchet is delivered, before being dropped into the basket for weighing. Under the bottom of each of these tubes or cylinders, is a flat slide of

steel, *K*, of the same thickness as the planchet to be weighed; the slides are cut out upon one end, in the shape of a semi-circle, so that they may slide up to the planchet, and push it from the tube into the receiving box, *P*, while the other end is made fast to a flat bar extending in front of, and parallel with, the plate supporting the tubes, and is fastened at either end upon the upper ends of levers, *L*, Fig. 3, which pivot upon the frame of the machine. The bottom ends of these levers are forked, and rest by friction rolls upon two separate cams, *M*, *N*, on the horizontal shaft driven by the worm wheel. These cams, as they rotate, act upon the levers, *Z*, causing a forward and backward motion. As they are moving forward, the slides, or feeders, *K*, are pushed forward, and, passing under the tubes, *J*, push a planchet out, so that it drops into the receiving box, *P*; in their backward movement, by means of a stop upon the under side of the feeders, they pull back a second slide, *O*, which to this moment has closed the opening at the bottom of the receiving box, and the planchet slips into the basket, *G*.

While the above operation has been taking place, the cam, *W*, Fig. 4, has been operating upon levers, *X*, at each end of the machine, one end of each lever passing out from under the frame, and resting by a friction roll upon the under side of the cam; the other end being connected to the weight, *Y*, suspended under the bed, *D*, upon which the balances are placed.

This weight rests upon one end of a rectangular lever pivoting upon a stud screwed into the frame of the machine. The other end of the lever is connected, by a link, *X′*, to a vertical lever, *Z*, which, at its lower end, pivots upon a stud in the frame; while the upper end is connected to, and supports, a plate upon which are fastened the delivery box, *S*, with its channel ways, as also the friction rolls which clamp the basket while the weighed piece is removed therefrom.

Fig. 5.

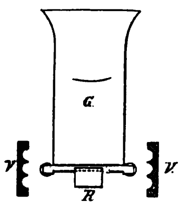


When, as before stated, the levers carrying the feed movements necessary to convey the planchet into the basket have, by their motion, deposited the planchet there, the third cam has moved so as to cause the brass clamps, *V*, Figs. 5 and 6, which, until this moment, have held the basket, to open and release their hold; while, at the same time, the brass cylinder, *H*, Fig. 3,

rises, and by the springs upon the upper ends of its arms, and the fingers upon the lower end, touches lightly the beam and baskets, quieting the same, and then immediately descends, allowing the beam to vibrate. The time allowed for the vibration is, in the case of those used in the Philadelphia Mint, five seconds.

As soon as the beam has assumed the position corresponding to the weight of the piece in the basket, the weight under the table, by the action of the cam, *W*, upon the lever, *X*, is lower upon the end of the rectangular lever, pressing it down, thereby moving the lever, *Z*, forward, causing the clamps, *V*, Figs. 5 and 6, to hold the basket in their grooves, and the slide, *R*, which closes the opening from the basket, is pressed back, and the planchet slips into the delivery box, and thence, through the channel ways, into the collecting boxes at the end of the machine.

Fig. 6.



When the planchet has passed from the basket, the weight, *Y*, commences to rise, and the vertical lever, *Z*, carrying the delivery box is forced back by a spring; as soon as it has moved far enough to allow the door from the basket to be closed, the next planchet is dropped in by the withdrawal of the slide, *O*, which closes the exit from the receiving box.

This machine was invented by Mr. Seyss, in the year 1871. Since then he has constructed 39, which are in use at the following mints: Vienna, Berlin, Kremnitz, Munich, Dresden, Hamburg, Stockholm, Copenhagen, Brussels, Darmstadt, Berne, Frankfort on the Main, Hanover, Costa Rica, and Philadelphia.

The first machine for this purpose was, as far as I am informed, invented by Baron Seguiers of Paris. Such a machine was ordered by the Government in the year 1852, and was received at our Mint in 1854; it was constructed for the weighing and sorting of half eagles only; the use of it was abandoned most probably from its incapacity to perform the work in a satisfactory manner; it still remains in the Cabinet of the Mint, and is a very pretty and ingenious piece of mechanism.

The only other practicable machine for the weighing and sorting of coins is that constructed by Napier & Sons, which is used in the Bank of England. It is worked by water power, and weighs 18 pieces

per minute, dividing the coins into three classes, while the Seyss machine will weigh 80 pieces, dividing them into the same number of classes.

By the introduction and use of the Seyss machine, the separate weighing of the silver coin will be accomplished, thereby preventing any silver coin passing from the Mint which shall not be within the legal allowance, viz., $1\frac{1}{2}$ grains light or heavy on each piece. The large number of silver pieces annually struck has heretofore prevented the weighing of single pieces, but with the aid of a sufficient number of the Seyss machines it is thought this can be done. The capacity of this machine, as compared with the amount of work that can be accomplished by one person, is as one to five; therefore the machine, attended by one person, will perform, in a given time, the same amount of work that would, by the use of the ordinary balance, require the services of five.

REPORT ON A STANDARD WIRE GAUGE.[1]

The Committee on a Standard Gauge have been constantly engaged, since their appointment, in the duties assigned to them. They have corresponded with different persons interested in the manufacture and use of gauges in this country, and have received from several of them important information..

They have also entered into correspondence with the governments of England, France, Germany, and Russia, through their consuls, and with Austria directly. The consuls of Germany and France have taken the greatest interest in the matter, and have communicated to your committee a large amount of valuable information relating to the gauges used in their countries. Prof. Tunner, of Leoben, Austria, one of our honorary members, has communicated information relative to the uses of gauges in Austria. The replies to the communications addressed by the English and Russian consuls to their respective governments, have not, as yet, been received.

Your committee commenced its labors, having in view to find a gauge which should be simple in its construction, not readily worn, capable of easy adjustment, and not too expensive to be used by the

[1] A paper read before the American Institute of Mining Engineers, at the Amenia meeting, October, 1877.

ordinary workman. With this in view, they have examined a large variety of gauges, and believe that all those in general use in the United States have passed under their inspection.

We find, as the result of our examination, that, although there are a great number of patterns, most of the gauges in general use differ but slightly in principle. The different systems may be divided into two general classes. These are—*first*, fixed; and, *second*, movable gauges.

Of the fixed gauges, there are three general types. These are, first, those made with slots, open at one end, the sides of which are intended to be parallel, as the ordinary wire gauge; second, those made with round holes made in a plate, with or without a plug corresponding to each hole to check the size, such as the Whitworth gauge, and the Stubbs wire gauge, better known in this country as the "twist drill" gauge.

In both these kinds of gauges, the slots and holes are designated by numbers.

The third kind of fixed gauge consists of a V, either cut into a sheet of steel, or formed by placing two bars of steel together at one end, and leaving them open at the other a fixed distance.

Of the movable gauges there are two types: Sliding calipers with verniers, with or without a micrometer screw for adjustment; and the micrometer screw gauge.

Your committee find that the gauges which are characterized by round holes or slots, designated by numbers, are only approximately correct. They not only differ according as they are made by different manufacturers, but in a package of a dozen made by the same manufacturer there often were very perceptible and annoying differences. They find that in the gauges with open slots the sides are rarely parallel, and that there are even greater variations in them than in the gauges made with closed round holes without plugs. They find that the numbers affixed to the slots and holes vary so much, on account of the differences in the width of the slots and in the diameter of the holes, as to be a constant source of inaccuracy, uncertainty, and annoyance. This variation has, in certain cases, been found to amount to as much as 50 per cent. of the weight of different wires of the same number which have been examined. It is, therefore, impossible to make even an approximative comparison of sizes, unless, besides the number, not only the kind of gauge, but also the name of

the maker, is specified, and that even then this approximation cannot be relied upon when the gauges have been worn from constant use or bad tempering.

The best example of the round holes with plugs is the Whitworth gauge, which is made of a thick plate of tempered steel. Each hole of the gauge is provided with a hardened steel plug, which fits it exactly. In all the recent gauges of this kind the system of numbers is abandoned. The plug is made of a given diameter, which is stamped in figures on each one. These diameters, generally, vary by thirty-seconds, sixteenths, eighths, quarters, and so on, each size having a hole and plug of its own, so that a complete set will consist of as many holes and plugs as there are fractional parts. To obviate the difficulty of the indefinite repetition of the plugs, they are sometimes made so that when any two, or even three, plugs are placed together, they will exactly fit the hole corresponding to the sum of their diameters. This arrangement is made to insure accuracy, as the multiplication of a very slight error would prevent even two plugs from fitting the hole corresponding to the sum of their diameters. When well made, this gauge is an instrument of precision; but it is evident that, in order to have such a gauge even moderately accurate, it must be a very expensive instrument, and altogether beyond the reach of an ordinary workman, or even of a manufactory with small capital; and that from the indefinite multiplication of holes and plugs, it must necessarily be very cumbersome. When they are used, there must always be two such gauges, one for comparison and one for use, and when the gauge is only very slightly worn it ceases to be an instrument of precision, and is then open to all the objections of the ordinary gauge with fixed holes.

Your committee, very early in the course of their investigation, formed the opinion that no reliance whatever was to be placed on the numbers of gauges, as an indication of size, except for the individual gauge to which the number was attached; and that the only accurate and scientific way of expressing the size of an article to be gauged was by some expression of its diameter, which should be more exact than numbers, and which would allow of an accurate comparison of all the dimensions by whatever gauge they were taken.

Your committee are supported in this opinion by the present practice among some European manufacturers who have recently acted in this matter, who have decided that a given number on a gauge shall

correspond to a given diameter expressed in fractions of the legal standard of length of the country; but as, in all fixed gauges made for ordinary commercial use, the diameter can only be approximately expressed, neither the number nor the diameter is ordinarily correct, so that there is a double source of inaccuracy, as the number does not express the exact diameter, nor the diameter the number.

Owing to the great liability to error, and the impossibility of correcting it, even in the most elaborate forms of this kind of gauge, your committee, early in the course of its investigation, after having themselves examined a large number, and having had communicated to them the results of examinations made by others, dismissed this class as being unsuitable, either from their defective construction, the impossibility of adjusting them when out of order, or their great cost, from their consideration as a standard gauge.

Your committee next turned its attention to the V gauge, which is made by placing together two pieces of hardened steel, so that they touch at one end, but are open a given distance at the other, the numbers or diameters corresponding to the opening being graved upon one or both of their sides. The accuracy with which measurements can be made with this gauge when it is new, and the jaws properly tempered, adjusted, and fastened, is surprising. Exceedingly minute differences, even in the diameters of the same wires, can be detected and measured with great nicety, but by constant use the gauge wears unevenly. It must then be taken apart, reground, and readjusted, which will generally cost more than the gauge is worth.

Your committee, while having the highest opinion of it for ordinary purposes, after some months of study abandoned the idea of recommending it as a standard gauge.

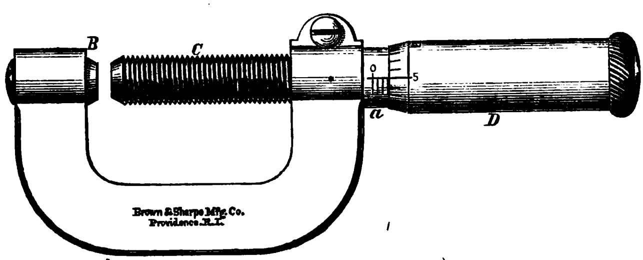
Their attention was then turned to the other two kinds of gauges, namely, the sliding gauge with a vernier, with or without a micrometer adjustment, and the gauge known as the micrometer gauge. The advantage of these gauges is great accuracy. The sliding gauge with a vernier necessarily wears, but the error of wear can be ascertained and allowance made for it, so that accurate measurements can always be made with it when it is worn.

In the micrometer gauge the wearing surfaces are so arranged that they can be adjusted with ease in a few moments. The wear between the male and female parts of the micrometer can be adjusted by a binding screw. This adjustment can be repeated as often as required,

so that the instrument will read with great accuracy until it is worn out.

Your committee assured themselves by actual trial that with such a gauge boys can very easily be taught to read the thousandth of an inch or the fortieth of a millimetre, and that it is practicable to read even the eightieth of millimetre.

The micrometer gauge is, of these last two gauges, the simplest. It consists of a micrometer screw, C, with a vernier attachment on D, is susceptible of easy adjustment, is not likely to wear, is not complicated, is less likely to get out of order than the other gauges, is more easily read, and requires less skill to read it than the sliding gauge with a vernier. Your committee are therefore of the opinion



that this gauge, which is shown in the above cut, is the gauge which should be adopted as the standard gauge.[1]

They are of the opinion that all gauges should be graduated so as to read fractions of an inch or of a millimetre, and that the sizes

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[1] Description of the Gauge.—The piece in the form of the letter U has a projecting hub, *a*, on one end. Through the two ends are tapped holes in one of which is the adjusting screw, *B*, and in the other the gauge screw, *C*. Attached to the screw, *C*, is a thimble, *D*, which fits over the exterior of the hub, *a*. The end of this thimble is beveled, and the beveled edge graduated into twenty-five parts and figured, 0, 5, 10, 15, 20. A line of graduations, 40 to the inch, is also made upon the outside of the hub, *a*, the line of these divisions running parallel with the centre of the screw, *C*, while the graduations on the thimble are circular. The pitch of the screw, *C*, being 40 to the inch, one revolution of the thimble opens the gauge 1-40 or 25-1000 of an inch. The divisions on the thimble are then read off for any additional part of a revolution of the thimble, and the number of such divisions are added to the turn or turns already made by the thimble, allowing 25-1000 for each graduation on the hub, *a*. For example, suppose the thimble to have made four revolutions and one-fifth. It will then be noticed that the beveled edge has passed four of the graduations of the hub, *a*, and opposite the line of graduation will be found on the thimble the line marked 5. Add this number to the amount of the four graduations, which is 100-1000, and it equals 105-1000, which is the measurement shown by the gauge.

should be expressed as the only means of insuring correct measurements, and not by numbers, which constantly lead to error. That this, while it insures great accuracy, presents no difficulty in practice, is shown by a number of experiments made during a period of several months, to ascertain the practical difficulty in the way of the adoption of this method by a member of your committee. The sizes of some of the steel bars, the orders for which were expressed in thousandths of an inch, are given below.

Sizes expressed in decimals of an inch, taken at random from the order book of a manufactory which has adopted this method:

15·5 × ·014	3·00 × ·0145	2·25 × ·059
15· × ·02	3· × ·018	2·25 × ·046
15· × ·014	3· × ·02	2·25 × ·040
5·25 × ·061	3· × ·0125	2·25 × ·038
4·50 × ·062	2·75 × ·030	2·25 × ·055
4· × ·024	2·75 × ·051	2·25 × ·020
4· × ·022	2·75 × ·035	2· × ·018
4· × ·071	2·50 × ·059	1·50 × ·032
3·475 × ·062	2·50 × ·022	·75 × ·095
3·25 × ·01	2·25 × ·031	·25 × ·062

The trial of this system by some of the manufacturers has resulted in banishing all the old forms of gauges from their workshops.

The conclusions which have been arrived at, for the most part independently, by the different members of your committee, and in which they unanimously agree, are:

1. The abandonment of the system of fixed gauges for commercial use.

2. The abandonment of the system of representing the diameters and sizes by numbers.

3. The adoption of the system of expressing sizes in thousandths of an inch or fractions of a millimetre.

4. The adoption of the micrometer gauge as the method of measuring sizes.

Your committee beg to acknowledge their indebtedness to J. B. Knight, Secretary of the Franklin Institute, in Philadelphia, for the reports of various committees on gauges of the Franklin Institute; to C. Hewitt, Esq., President of the Trenton Iron Company, for a large number of measurements of wire made with different gauges; to P. Ritter von Tunner, of Austria, for the description of the kind of gauges used in Austria; to the German Consul, for his interest in procuring from

Germany a report of their gauge system; to the French Consul, for his interest in the work of the committee; and to the Minister of Agriculture, Commerce, and Public Works, for a complete description of the gauge system as used in France.

Your committee is, however, particularly indebted to Darling, Brown & Sharp, of Providence, who have loaned to them, without charge, all the gauges which they manufacture, for comparison, and have contributed besides a very large amount of information on various matters connected with this subject.

All of which is respectfully submitted.

T. Egleston, *Chairman.*
Wm. Metcalf.
Jos. D. Weeks.

THE HAYFORD PROCESS AND APPARATUS FOR PRESERVING TIMBER.

By Edward R. Andrews, of Boston.[1]

Mr. President and Gentlemen, Members of the Franklin Institute: —I wish to invite your attention, this evening, to a consideration of the natural and mechanical principles involved in the "Improved Processes and Apparatus for Preserving Wood," patented by Ira Hayford, Boston.

As introductory to the main subject, a few statistics of the rapid consumption of the timber of this country, an explanation of the causes of decay in wood, and the scientific principles which are the basis of every successful method of arresting and preventing decay, will not be out of place.

The subject of *wood-preserving* has not received the attention of scientific and practical men in this country, which its importance as a valuable industry demands for it. In Europe it is not only well understood, but preserved wood is generally used.

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[1] Paper read before the Franklin Institute, January 16th, 1878.

Maxime Paulet, a French chemist, in a large octavo volume on this subject, published in 1874, mentions not less than 173 different processes and apparatus, which have been patented or described in scientific works since the year 1700.

The most valuable systems were discovered between 1832 and 1838. Kyan, Bethell, Burnett, and Boucherie—whose names have been given to the methods employing corrosive sublimate, creosote, chloride of zinc, and sulphate of copper—introduced their several systems during that short period. All of these are in use in Europe, and scarcely any others, three of them, to a very limited extent, in this country.

In Europe, the use of preserved timber is the rule; here, it is the rare exception. Abroad, no question arises as to using preserved wood, and seldom as to the method; except in France, where sulphate of copper is largely used for railway ties, the Bethell system, or the impregnation of the pores of wood with the heavy oils of tar, known as creosote oils, has almost entirely superseded every other system.

In this country, the apparently inexhaustible supply of timber has retarded the general use of preserved wood. Yet, for some years, it has become evident that our supply is not inexhaustible. The drain is enormous; many parts of our country have been stripped of forests altogether. The statement is made, in *Scribner's Monthly* for December, that the annual lumber product of the whole country is ten thousand millions of feet. A very considerable portion of this product is to replace what was cut four to ten years before, and has decayed.

Consider for a moment the consumption of wood in the one item of railroad ties. Massachusetts, employing mostly chestnut ties, which last on an average six years, uses up in this way, annually, a volume of lumber nearly equal to the whole product of Maine; and the 80,000 miles of track in the whole country, allowing four years as the average life of ties, actually use up in ties alone one thousand six hundred millions of feet annually, or equal to one-sixth of the timber product of the whole country.

Add to this the consumption of wood for fences along the lines of railways, the bridges, platforms, etc., and it is easy to see that if some effort be not soon made to lengthen the life of railroad timber, the supply will become insufficient.

There are also 76,000 miles of telegraph poles, requiring for their renewal annually 43,620,000 feet of wood, or nearly equal to the product of the State of Maine. Telegraph poles were first creosoted in England, twenty-seven years ago, and are as sound as at first, to-day. The English government is now creosoting all the telegraph poles in the United Kingdom.

In view of these facts, added to the cost of labor attending the renewal of decayed wood, it would seem that this country ought to be alive to the importance of preserving wood, in view of the results of European experience.

I do not find there is any lack of interest in this subject, only a lack of knowledge and of faith. That there is a lack of faith is not strange, because, as a rule, preserving has not added much to the life of timber in this country. This is, no doubt, partly due to the fact that those who have constructed works here, have put up a flimsy structure to fill some contract, or had some stock-jobbing operation in hand, but also partly to the fact that the systems in use abroad are not fully adapted to meet the wants of this country.

Had either European system been so, it certainly would have become general ere this. Our railroad engineers would not have continued the use of natural wood for ties, which last only four to six years, if through the use of the Bethell system their life could have been increased to twenty or thirty years, as in England.

Here let us consider what decay in wood is, what it is caused by, and what is needed to prevent it. There are two kinds of decay, known as *Wet Rot* and *Dry Rot.*

Wet Rot takes place in wood containing sap, which is exposed to moisture. It often commences in a living tree. It shows itself in the red streaks in the wood when felled, and woodmen recognize its existence even before the tree is cut down. It is wet rot which destroys railroad ties, fence posts, telegraph poles and bridge timber. It is hastened by alternate moisture and dryness.

Dry Rot, so called, needs moisture for its development as well as wet rot. It occurs in close, confined, damp localities, where there is imperfect ventilation. As a rule, it flourishes most actively in unseasoned lumber, but it also attacks seasoned lumber, when so placed that it can absorb moisture from its surroundings. *Dry Rot* is that sort of decay which is found in cellars and basements, between the

ceilings and floors of houses, etc. Wood used in such localities is often already in a state of decay when placed there. It comes by cars or vessel direct from the saw-mill, and is framed at once, reeking with sap and moisture.

It is dry rot which destroys vessels, owing to confined air; the short life of wooden vessels is mainly attributable to this cause, and several of the methods for preserving wood were first used to prevent decay in the British Navy.

In localities where dry rot exists, and has destroyed one set of timbers, the seeds of decay are there still, ready to attack new timbers, unless the conditions can be entirely changed by ventilation or otherwise, and often such a change is impossible.

What is the cause of wet rot and dry rot? It is due primarily to the fermentation of the albumen of the sap, which commences as soon as the necessary conditions, heat and moisture, are provided. In a living tree, the unmatured sap rises from the ground through the sap wood, and after being transformed by the action of the leaves into true sap for the formation of woody fibre, it descends within the bark loaded with sugar, acids, albumen, etc., and forms the annual growth of wood, holding in abundance rich sap within its cells and fibres. So long as the tree lives, these processes go on naturally, but when the tree is cut down, and the leaves no longer perform their functions, the abundant sap clogs the pores, and is in a favorable condition to be acted on by heat, and begins to ferment.

Fermentation causes the rapid development of countless myriads of spores of fungi always present. Animalculæ and insects follow, and the woody fibre is in time disintegrated, and although perhaps retaining the form of wood, it has lost all its strength and tenacity, and crumbles into pieces at the slightest blow. Rot is, then, the growth and development of fungus and animal parasites.

Preserving Processes.

The prevention of the development of fungus, or its destruction with the animal life it nourishes, is, then, the object of the various processes for preserving wood. The coagulation of the albumen of the sap is the only result obtained by the use of the metallic salts. Coagulation prevents the albumen from fermenting, and the spores of fungi lie dormant; both vegetable and animal life are arrested. As

a protection against dry rot, where wood is not exposed to moisture, these systems are useful, but when wood is exposed to water, they are of little value, as a rule. They consist in impregnating the pores of wood with watery solutions. It is certain they will partially redissolve by water, and leave the wood unprotected, always liable to absorb water carrying with it destructive elements.

It is important, then, that the public should not confuse creosoting with Burnettizing, etc. They only act chemically upon the sap, but creosote oil, containing carbolic acid, cresylic acid, etc., not only produces the same result chemically, but also secures *dryness*. Creosoting fills the pores of wood with an insoluble oil, and covers the fibres with a film, which protects them from absorbing destructive elements from extraneous sources. The oil, which saturates the sap wood, and the outer pores of the heart wood, resinifies and hardens under the action of the air, and forms a waterproof and air-tight covering to the wood. If the heart wood be not too dense, it also absorbs a large quantity of oil, otherwise the oil absorbed by the sap wood works inwardly, being very penetrating in its character, and, in time, can be plainly seen through the whole tissue.

It is *dryness*, then, and the waterproof and air-tight qualities imparted to wood by its impregnation with creosote oil, which give it its superiority over every other substance used for preserving wood. The presence of heat and moisture is necessary to induce decay; heat without moisture is harmless. Wood absolutely dried by some artificial process of desiccation will not decay, if it can be kept perfectly dry afterwards; hence, wood, which has been dried, has been preserved. Wood once dried, and then so protected that it can under no circumstances absorb moisture, has been rendered practically imperishable, except from wear.

When wood has been treated by the Bethell system, if the work has been faithfully done, it will not absorb moisture, and is, therefore, well preserved against decay.

Why, then, is not the Bethell system sufficient, you will ask? The answer is simply because only dry wood can be effectually treated by the Bethell process, and in this country we must treat green lumber. No system of wood-preserving can be made practicable here, which does not embrace some effectual method of drying green wood rapidly.

This defect of the Bethell system has always been recognized in Europe, where ties and timber intended for creosoting, are stacked up from nine to twelve months to season.

At a discussion on the preservation of telegraph poles, in 1876, Mr. Braine, Superintendent for J. Bethell & Co., London, made these remarks: "Dryness is the principal quality required in timber that is to be creosoted. Timber is sometimes delivered *dripping wet*, and the creosoting firm expected to creosote it without delay. * * * * * It is perhaps better that timber should not be creosoted at all than creosoted moist."

With us timber is used directly from the cars or vessel. We cannot wait for timber to season. It is not cut from the log until needed for construction. We must be prepared to take timber as it comes from the saw-mill, and in a few hours season and preserve it.

The Bethell system will not do this; oil and water will not mix together. So long as the pores of wood are reeking with sap and river water, it is impossible to inject into them any preservative substance. Hence, it is evident that the Bethell process needs some radical modifications before it can be adapted to the wants of this country. These modifications are precisely what have been made in the *Hayford* patents.

The important claims of the Hayford process are: *Dryness* before impregnation with any preservative substance, a complete coagulation of the albumen of the sap by heat, the evaporation of the watery portions of the sap, and the withdrawal of all moisture, sugar, acids, etc., in vacuo, leaving a pure wood fibre, fully preserved against decay, except from contact with air and moisture. There is no patent for the use of creosote oil. The Hayford patents cover improved processes for preparing wood to receive any preservative substance required, and apparatus for injecting such substance into the pores of wood thoroughly and rapidly.

Apparatus.

I will now describe, as clearly as I can, the apparatus used in the Hayford process, and then try to show wherein it brings about the results I claim. The apparatus is simple and strong. At my works at South Boston, I have endeavored to have perfect security from accident, and, at the same time, the best-fitted and strongest plant ever erected for wood preserving.

It consists mainly of an 85-horse boiler, a pump, a tank to contain oil, and a cylinder in which the wood is treated. The *cylinder* is the most important part of the works, and upon its perfect construction depends the commercial success of the enterprise. It is 100 ft. long, 6 ft. in diam., made of $\frac{1}{2}$ inch boiler iron steam riveted. On either end, a cast gun-iron ring is riveted, which serves as a jam to a wrought-iron door made of plates $\frac{5}{8}$ inch thick, bent to a semi-globular form and riveted to a gun-iron ring of same dimensions as the ring on the cylinder. This door is hung to the cylinder by a hinge, which, however, acts as a guide only, the weight being supported by a strong wheel, which rolls on a track with a solid foundation. A rubber gasket makes the joint between the rings perfectly tight. The cast-iron rings are pierced with bolt holes, through which 36 bolts pass. On one end of each bolt is a case hardened nut, and at the other is pierced an eye, into which slips one of a series of steel keys, arranged upon a ring, which revolves about the cylinder by a screw motion, by which means all the bolts are fastened or unfastened at once. It is necessary to give a few turns to the nuts with a wrench, to make the joints perfectly tight, before commencing a treatment, or to loosen the strain when the treatment is over, and the doors are to be opened; but by this simple mechanical contrivance, the great labor of opening and closing the doors is made comparatively easy.

The cylinder rests on rollers, to allow for expansion and contraction, supported on brick piers. This cylinder is a perfect piece of boiler work, and has been tested by hydrostatic pressure of 200 pounds to the square inch. There is no leakage during the process, when the pressure reaches from 100 to 150 pounds. Great annoyance has been frequently experienced with cylinders made for wood preserving on account of leakage, and danger also from want of strength in the heads, generally of cast iron, which broke under the required strain.

A railway track, 3 feet 4 inches wide, runs through the cylinder, and extends 100 feet beyond at either end, so that iron cars can be loaded with lumber at one end and be discharged at the other. Between the tracks, at the bottom of the cylinder, lies a coil of steam-pipe 1400 feet long, which connects with the boiler at one end, and at the other has outlets both with the outer air and with the inside of the cylinder, that the steam, after passing through the coil, can be allowed to escape into the cylinder when desired.

A series of perforated pipes is arranged around the inside of the cylinder, for the purpose of introducing the oil. These are connected with the oil tank. They are so arranged that, when the oil is let on through them, every stick of wood in the cylinder is at once bathed with oil.

The *oil tank* is simply a receptacle to contain the oil, and of capacity sufficient for the purpose. It is strong enough to stand a pressure of 100 pounds to the square inch. A coil of steam-pipe, connected with the boiler, is laid through it for the purpose of heating the oils to the required fluidity.

A simple, but powerful, pump is so provided with valves and pipes that by opening one set of valves and pipes it is a force pump, and by closing these and opening another set it becomes a vacuum pump. A water-jacket around the air-chamber keeps it cool while in operation. The necessary piping to connect the parts together completes the apparatus.

Hayford Process.

The first part of the process is for the purpose of drying the timber.

The wood to be treated has been placed upon iron cars, and run into the cylinder, which is hermetically closed. Steam is then admitted through the coil in the cylinder, and after passing through the coil, it escapes into the cylinder itself. The temperature in the cylinder very soon reaches 180° Fahr. It rises very slowly from this point, the evaporation of the sap and moisture in the wood tending to cool the temperature. It is best that the heat should increase gradually and that it should be kept moist. If allowed to be too dry, the outer fibres of the wood naturally harden, and thus prevent the escape of the moisture within. To avoid this, and also to save all the heat, the exhaust from the pump is also admitted into the cylinder. The pump is set at work to force atmospheric air into the cylinder, until the pressure gauge shows a pressure of 30 to 40 lbs. to the square inch. The object of this is to keep the wood from checking; green wood, in large dimensions, when exposed to high temperature, has a tendency to check. A vacuum forms about the wood, arising from the condensation of steam, and the expansion of the moisture within the wood tends to throw apart its fibres. This tendency is counteracted by the atmospheric pressure above stated.

And thus a higher degree of heat can be used in drying the wood without injury to its fibres. 250° to 270° are sufficient to evaporate the sap.

During the steaming process, a pipe in the bottom of the cylinder is kept open, to allow the escape of the condensation. By the same means is maintained a current of hot air, which is very efficacious in drying wood. The time necessary for drying wood in this process depends upon the quantity of moisture to be got rid of, and the size of the timber. Four or five hours suffice for boards and 2-inch plank, while ten or twelve are required for heavy timber.

Albumen coagulates at 140°, so that that result—the only one claimed for the Burnettizing and Kyanizing processes—is easily secured; but the sap and moisture cannot be got rid of, until they have been turned into vapor. Hence the necessity for continuing the steaming process until it is certain that all the portions of the wood containing sap and vapor have been heated to above 212°.

When this point is reached, the direct steam is cut off, all valves opened, and the air pumps kept at work to drive from the cylinder all the steam, vaporized sap and condensation, which remain in the cylinder; in other words, to free the cylinder entirely. This occupies about an hour, and closes the second part of the process. Heat is constantly maintained through the radiation from steam coil. We then commence to pump a vacuum.

The cylinder is once more made tight. The valves in the pipes connected with the pump, which made it a force pump, are closed; and those opened, which change it into an exhaust or vacuum pump. The vacuum pump is then set to work. There is, at this time, no appreciable amount of moisture in the cylinder, except what exists in the pores of the wood in the form of vapor. The vacuum pump has worked but very few minutes, however, when the vapors, partly condensed in the pump, begin to pour from the nose of the pump, and they continue to come for hours, filling, if the wood be green, many barrels with sap.

This shows the effect of the steaming process. If a cold vacuum had been pumped, when the cylinder was first closed, it could be easily done in less than an hour, but no water would have come through the pump, and the wood would not have parted with its sap. It is a common mistake to suppose that a vacuum alone will withdraw sap from wood. But after steaming, when the sap has been

turned into vapor, then it is drawn out by the force of the vacuum pump, yet the vacuum is reached very slowly, on account of the vast quantity of moisture which is drawn from the wood; five or six hours often elapse before the vacuum gauge indicates 24 or 26 inches of vacuum. But the sap having been withdrawn, the vacuum extends into the interior of the wood, if it can be properly so expressed, so that when the oils are let in, they are absorbed into the very heart of the wood.

This brings us to the last step in the Hayford process, namely, the impregnation with the preserving material. During the drying process, steam has been admitted to the coil in the oil tank, bringing the temperature up to about boiling point, to render the oils very limpid and penetrating. Creosote oil is heavier than water, weighing about $9\frac{1}{2}$ pounds to the gallon, it congeals at about 60°, so that heat is needed to make it flow freely.

Impregnation.

I have previously explained to you that the oil is admitted to the cylinder through a series of perforated pipes, arranged around the inside of the cylinder. A pressure of about 60 pounds to the square inch is brought to bear upon the top of the oils in the oil tank; this pressure, together with the drawing force of the vacuum, make a force of about 75 pounds to the square inch, with which the oils are sucked and driven into the cylinder. Every stick is at once bathed with oil. The wood—being in a soft, somewhat spongy condition, the fibres porous, and the pores open—absorbs at once the hot, penetrating oil. If the wood be of a porous character, like pine, it absorbs all the oil required with the first flowing over of the oils, without any pressure; but if the fibre be solid and close, and the timber of large size, a further pressure of from 60 to 150 pounds is needed during a certain length of time to make the impregnation complete. But the wood having been put into a condition to absorb the oil, the impregnation is more rapid and more thorough than by the Bethell process, where no other means are relied upon than a pressure upon hard, air-dried timber in a cold vacuum.

The process is now completed, and the doors at either end being opened, the lumber treated is withdrawn, and another charge takes its place.

[To be Continued]

LIQUEFACTION OF OXYGEN.[i]

Translated by W. H. Greene, M. D.

At the séance of l'Academie des Sciences of December 24th, M. Dumas presented the results of independent experiments of MM. L. Cailletet and Raoul Pictet upon the liquefaction of oxygen. He first read the following passages from Lavoisier, justly considered by the French savants as the founder of chemistry:

"Let us consider for a moment the condition of the different substances which compose the globe, if its temperature were suddenly changed. Suppose, for instance, that the earth were suddenly transported to a much warmer region of the solar system, to a region, for example, where the temperature is much higher than that of boiling water; in a short time, water and all of the liquids capable of vaporization at a temperature near that of boiling water, and even many metallic substances, would expand and become transformed into aeriform fluids, which would then become part of the atmosphere.

"By a contrary effect, if the earth were suddenly transferred to an intensely cold region, for example that of Jupiter or Saturn, the water which now forms our rivers and seas, and probably the greater number of liquids with which we are acquainted, would be transformed into solid mountains. * * * *

"Under this supposition, the air, or at least a part of the aeriform substances which compose it, would cease to exist in the state of invisible fluids, the proper amount of heat being wanting; it would therefore assume the liquid state, and this change would produce new liquids of which we have no ideas."

The priority of the discovery of the liquefaction of oxygen unquestionably belongs to M. L. Cailletet, but the researches of M. Pictet are much more thorough. The following extracts from his paper, which was presented by M. Dumas, give his results.

If pure oxygen or oxide of carbon be enclosed in a tube of the form which I have described,[ii] and placed in the compressing apparatus which was operated before the Academy[ii]; when the gases are cooled to — 29° by the aid of liquid sulphurous anhydride, both retain the gaseous condition. But if the pressure be suddenly relieved, that

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[i] *Comptes Rendus*, lxxxv, p. 1212.

[ii] *Comptes Rendus*, lxxxv, p. 851. Also see page 127, this No.

which according to the formula of Poisson should produce a temperature at least 200° below the starting point, an intense mist immediately appears in the tube, produced by the liquefaction, and perhaps the solidifaction of the oxygen or oxide of carbon. * * * *

This mist is produced by oxygen, even at the ordinary temperature, provided that time be allowed that it may lose the heat which it has acquired by compression alone.

These experiments were repeated in the presence of a number of scientific men on Sunday, 16th of December, 1877, at the *chemical laboratory of the École normale superieure.*

The following is a description of the apparatus and method of M. Raoul Pictet, of Geneva, whose results were obtained at about the same time.

A and *B* are two compound exhausting and compressing pumps, so coupled that while one exhausts, the other compresses, and that there may be the greatest possible difference between the effects of exhaustion and compression. These pumps operate upon liquid sulphurous anhydride contained in the annular recipient *C*. The pressure in this receiver is such that the sulphurous anhydride evaporates at a temperature of —65°.

The sulphurous anhydride thrown out by the pumps is conducted into a condenser *D*, cooled by a stream of cold water; it there liquefies at + 25° and under a pressure of 2¾ atmospheres. The liquid anhydride returns to the receiver *C* by a narrow tube *d*, as it is condensed.

E and *F* are two pumps precisely like the preceding, and coupled in the same manner. They operate upon liquid carbon dioxide contained in the annular receiver *H*. The pressure in this receiver is such that the carbon dioxide evaporates at —140°.

The carbon dioxide thrown out by the pumps is forced into the condenser *K* surrounded by the receiver *C*, cooled by the sulphurous anhydride, and which is at the temperature—65°. It there liquefies under a pressure of 5 atmospheres.

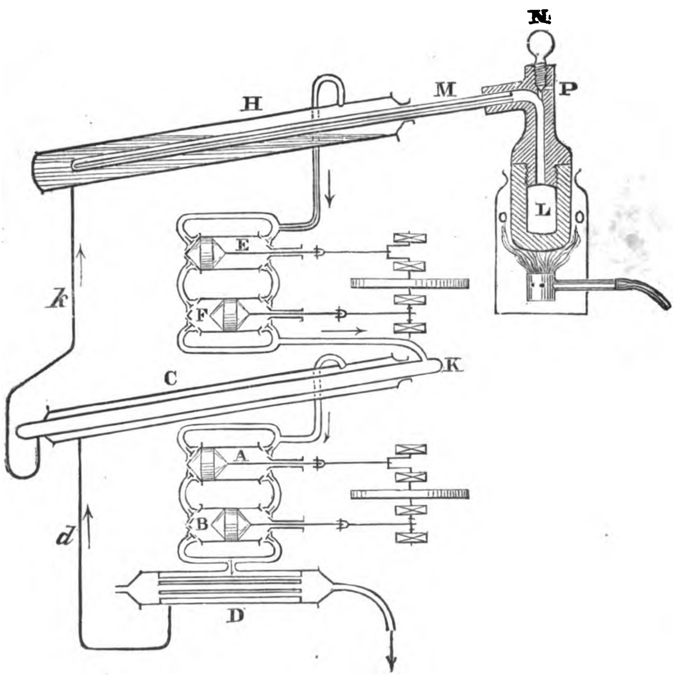
The carbon dioxide returns to the receiver *H* by the narrow tube *k* as it is liquefied.

L is a wrought-iron retort, thick enough to resist a pressure of 500 atmospheres. It contains potassium chlorate, and is heated so that pure oxygen is disengaged. It communicates by a tube with the tube *M* of very thick glass and 1 metre long, which is surrounded

by the liquid carbon dioxide in the receiver *H* at a temperature of —140°.

An iron plug screwed into the tubulure of the retort, permits the uncovering of an orifice *P*, open to the air. After the apparatus has been in action several hours, the pumps being worked by a 15 horse power engine, and when all of the oxygen has been disengaged from the chlorate, the pressure of the gas in the tube is 320 atmospheres, and its temperature —140°.

Fig. 1.



On suddenly opening the orifice *P*, the oxygen escapes with violence, producing an absorption of heat sufficiently great, that a part of it liquefies and appears in the tube, and is thrown out of the orifice if the apparatus be inclined.

It should be added that the quantity of liquid oxygen contained in the tube 1 metre long and 0·01 metre in internal diameter, occupies a little more than one-third the length of the tube, and was thrown out in a liquid jet from the orifice *P*.

[As a supplement to Dr. Greene's communication, we add the following extracts from the *Comptes Rendus.*]

M. Dumas, after analyzing the notes of Cailletet and Pictet, read a letter which Cailletet had addressed, on the 2d of December, to M. H. Sainte-Claire Deville, and which Deville had deposited on the next day, as a sealed package, with the Secretary of the Academy.[1]

M. Deville added the following explanation:

"M. Cailletet repeated his experiments on the condensation of oxygen in the laboratory of the Normal School, on Sunday, Dec. 16th, with perfect success. His note was not published earlier, because he was a candidate for corresponding membership, to which he was elected at the sitting of Dec. 17th, and he did not wish to urge any consideration of his work until its results had been confirmed by an experiment before competent judges. On the 17th, the day of his election, it did not seem fit to publish a fact of so great importance, inasmuch as the secret committee had not been able to discuss it in their session of the 10th; happily, I took the precaution, on the 3d, to have the perpetual Secretary sign and seal the letter which announced his discovery. His priority is therefore undeniable. I ought, however, to add that the remarkable accomplishment of M. Raoul Pictet is none the less meritorious. His mode of operation is totally different from the process employed by M. Cailletet. The process of cooling, founded on the expansion of a gas or of a vapor, a principle which had not yet been applied, and the simple apparatus of M. Cailletet, allow us to make a lecture experiment upon the resistance to condensation of divers gases which have been thought incoercible, which is very instructive, and very valuable for future researches of the same order.

"It is ten years since M. Cailletet laid the foundation of his discoveries. Desiring to obtain, under all circumstances, precise and rigorously measured results, he long since prepared special manometers, which he described in our *Comptes Rendus*, and he studied carefully the thermometric apparatus of M. Regnault and M. Berthelot. For this reason he now speaks, with well-grounded reluctance, of pressures determined by metallic manometers, and of temperatures marked by alcohol thermometers. Were it not for these absorbing

[1] The note contained the announcement which is embodied in the "Items" in this number of the JOURNAL.

studies, relative to the precision with which he wished to express the result of his experiments, he would long since have demonstrated the facts which he has published about gases, especially those relative to nitric oxide, carbonic oxide, and oxygen."

M. Jamin stated that the possibility of liquefying or solidifying oxygen is now demonstrated; the two experiments establish it; that of M. Pictet adds little to that of M. Cailletet, for if the former announces that he has seen oxygen in liquid form, everything seems to indicate that the sight was a very transient one. On the other hand, the mist observed by M. Cailletet at the moment of the escape, shows that the oxygen ceased to be transparent or gaseous, and that it had become solid or liquid. To have seen the liquid or the mist, without collecting either, is substantially the same thing. The final experiment is yet to be made; it will consist in keeping oxygen liquid at its boiling point, as in the case of nitrous oxide, or in the solid state, like carbonic acid, preserving itself in one of these conditions, because of the enormous latent heat which gasification requires.

M. Dumas added that he regarded the independence of the researches of MM. Cailletet and Pictet as satisfactorily established; pursuing the same object, creating methods and apparatus, which were not easily thought out, each on his side arrived at the same result, without knowledge of the other's labors, an occurrence which is frequent in the history of science.

M. Regnault informed the Academy that he was present five years ago, at the first attempts made at Geneva, by M. R. Pictet, and by M. de la Rive, to obtain the liquefaction of gases. He was struck by the remarkable ingenuity of the apparatus.

M. Berthelot, without forgetting the originality of M. Pictet's experiment, observed that M. Cailletet's experiments were the necessary results of his researches on the liquefaction of acetylene and nitric oxide, published in the *Comptes Rendus* (sittings of Nov. 5th and Nov. 26th). He called special attention to one circumstance of Pictet's remarkable experiment. The decomposition of chlorate of potash into oxygen and chloride of potassium, is not stopped by a pressure of 320 atmospheres. It is probable that the velocity of the reaction is changed, and, perhaps, also the temperature at which it is accomplished; but the reaction itself does not cease. This is a new proof in support of opinions already announced by him upon this important

question of chemical physics, opinions which were at first contested, but which new observations are continually confirming.

At the close of the sitting, M. Dumas received a copy of the following telegram:

"*Geneva*, 24 *December*, 4 *h*. 15 *m*., *P. M.*

"Second experiment perfectly successful. Many spectators. Same to-day as Saturday. Inform M. Dumas.

"PICTET."

On Wednesday, the 26th inst., M. Dumas received the following letter:

"I received yesterday, from Paris, a telegram announcing the kind interest that you have taken in the announcement of the liquefaction of oxygen, which was accomplished on Saturday last in my laboratory.

"I especially desire to thank you for communicating the result, yesterday, to the Academy of Sciences, before receiving the complementary details, which I now furnish you.

"The result at which I have been aiming for three years, is the experimental demonstration that molecular cohesion is a general property of bodies, without any exception. If permanent gases could not be liquefied, it would be necessary to conclude that their constituent particles have no mutual attraction, and, therefore, escape this law. In order to bring the molecules of a gas as near together as possible, and thus to liquefy it, the following conditions are indispensable:

"1. To have the gas absolutely pure. 2. To be able to dispense with extreme pressures. 3. To obtain an intense cold, and a subtraction of heat, at these low temperatures. 4. To secure a great surface of condensation at these low temperatures. 5. To be able to use the expansion of gases from the great pressure to the atmospheric pressure, an expansion which, when added to the foregoing conditions, compels liquefaction.

"With the fulfilment of these five conditions, when a gas, under a pressure of 500 or 600 atmospheres, is maintained at a temperature of —140° or —150°, and is suddenly allowed to expand to the atmospheric pressure, one of two things is necessary: either the gas liquefies under the law of cohesion, and yields its heat to the portion of gas which expands and escapes in gaseous form; or, if the law of cohesion is not universal, the gas must pass through the absolute

zero. In other words, it must be inert, dust-like, without consistency. The work of expansion would be impossible, and the loss of heat, absolute.

"Convinced of this reality, which thermodynamic equations assert by conclusive figures, I have sought to contrive a mechanical arrangement which would satisfy these divers conditions, and I have fixed on the following:

"I take two suction and force pumps, such as I use in my ice apparatus, and couple them so that the exhaust of one corresponds to the compression of the other; the exhaust of the first communicates with a tube $1{\cdot}10^{m}$ long, and $12{\cdot}5^{c}$ in diameter, filled with liquid sulphurous acid. Under the influence of a perfect vacuum, the temperature of this liquid quickly falls to — 65°, and even, in extreme cases, to 73°. Within this tube of sulphurous acid passes a second tube, having 6 centimetres exterior diameter, and the same length as its envelope. These two tubes are connected at bottom. In the central tube I compressed carbonic acid, prepared by Carrara marble and chlorhydric acid. The gas was dried, and collected under an oil gasometer with a capacity of 1 cubic metre. Under a pressure ranging from 4 to 6 atmospheres, the carbonic acid readily liquefies; the resulting liquid is conducted by itself in a copper tube, 4 metres long and 4 centimetres in diameter.

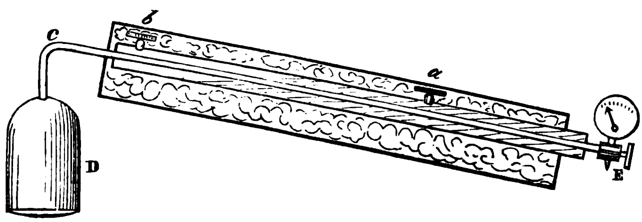
"Two pumps, coupled like the first, draw the carbonic acid, now from the gasometer, now from the tube filled with the liquefied gas. The access to the pumps is governed by a three-way cock; a screw-valve intercepts at will the entry of the liquid carbonic acid into the long tube; it is placed between the carbonic acid condenser and this long tube. When this regulating valve is closed, and the two pumps exhaust the vapor of the liquid carbonic acid contained in the long tube, there results the greatest possible reduction of temperature; the carbonic acid is solidified, and falls to about — 140°. The subtraction of heat is maintained, by the working of the pumps, at the rate of 100 strokes per minute, and 3 litres per stroke. The sulphurous acid tube and the carbonic acid tube are both wrapped with sawdust and rags, to diminish the influence of radiation.

"In the interior of the carbonic acid tube passes a fourth tube, designed for the compression of oxygen; it is 5 metres long, with 14 millimetres exterior diameter, and 4 millimetres interior diameter. This long tube is, consequently, imbedded in the solid carbonic acid,

and its whole surface is exposed to the lowest temperature that can be obtained. These two long tubes are joined, by their bases, to the carbonic acid tube, so that the small tube projects about 1 metre from the other. I bend this portion towards the ground, giving the two tubes a slightly inclined position, but deviating little from horizontal, as represented in the subjoined cut. The small central tube is bent at *c*, and screwed to the neck of a strong forged iron retort, with walls 35 millimetres thick. The height is 28 centimetres, and the diameter 17 centimetres.

"This retort holds 700 grammes of chlorate of potash and 256 grammes of chloride of potassium, mixed together, melted, then bruised in a mortar, and introduced into the retort perfectly dry. I heat the retort when the two circulations of sulphurous acid and car-

Fig. 2.



a, entrance of the liquefied carbonic acid.
b, exit of the vapors withdrawn by the suction pump.
The same retort and tubes are shown in the large cut at *L*, *M*, *H*.

bonic acid have reduced the temperature sufficiently. The decomposition of the chlorate of potash goes on gradually at first, and rapidly towards the end of the operation. A manometer, at the end of the long tube, enables me to observe constantly the pressure and the progress of the reaction. It is graduated to 800 atmospheres, and was made expressly by Bourdon, of Paris, this summer.

"When the reaction is over, the pressure exceeds 500 atmospheres, but it soon falls a little, and stops at 320 atmospheres. If, at this moment, the terminal screw-valve, *E* (or *P*, Fig. 2,) is opened, a liquid jet escapes with extreme violence. Closing the valve, and reopening it some minutes later, a second jet, but less copious, is seen. Coals slightly kindled, placed in this jet, burn with extraordinary violence. I have not yet been able to collect this liquid, because of its great projectile force, but I am trying to contrive a receiver, previously cooled, which will perhaps enable me, by means of cloths, to retain a little of it.

Yesterday (Monday) I repeated the experiment before a large portion of the members of our Physical Society, and we had three successive well-marked jets. I cannot yet determine the minimum pressure required, but it is evident that I have had too great a pressure, owing to an excess of gas accumulated in the retort, and which could not condense in the narrow space afforded by the inner tube.

"I expect to use a similar arrangement for attempting the condensation of hydrogen and nitrogen, and I rely on the possibility of maintaining the low temperatures very easily, thanks to the four great pumps at my disposal, moved by a steam engine.

"I believe it is in this direction that we should work in order to effect obstinate condensations, for the tensions of saturated vapors are a direct function of the temperature. I am having a sketch made of the apparatus that I used, and I shall make it a pleasure and a duty to send it to you this week. I have learned with lively interest that M. Cailletet has arrived at the same result as I, and almost at the same moment. I know nothing of his process, but I think that we shall not delay to exchange our ideas, by correspondence, upon these interesting problems.

"I beg you to excuse the brevity of this description. I will try to complete it soon, adding some figures and equations which give these results a more scientific character."

Description of M. Cailletet's Apparatus.[1]

The apparatus which I use is composed of a hollow steel cylinder, with walls thick enough to resist the pressure of many hundred atmospheres. The upper part of the apparatus has a screw groove, for attaching, by means of a bronze nut, the glass reservoir which holds the gas to be liquefied. This reservoir is formed of a thick tube of small diameter, connected with a larger tube, which plunges into the mercury with which the cylinder has been filled.

The large tube is then submitted, both internally and externally, to equal pressures, so that it may be of considerable size, notwithstanding the high pressures which it must support. The tube of

[1] From *Comptes Rendus*, Nov. 5th, 1877.

small diameter, which surmounts it, is exposed to the internal pressures, which produce liquefaction, while its outer walls only sustain the atmospheric pressure. The tube passes vertically through a metal shoulder-piece, so that all the phases of liquefaction can be followed by the naked eye. For greater security, it is well to surround this part of the apparatus with a larger cylinder filled with water.

The gas is compressed by a hydraulic pump, with the intervention of a layer of mercury. The apparatus is so simple, and so easy to operate without danger, that I hope it may be commonly employed in lectures and in laboratories, for repeating experiments of this kind.

LIQUEFACTION OF NITROGEN, HYDROGEN AND AIR.

Note by M. L. CAILLETET.[1]

I have continued my experiments upon the liquefaction of gases, and I am happy to inform the Academy that I have succeeded in liquefying nitrogen and atmospheric air. Hydrogen itself gives evidence of liquefaction, as I will presently show. I submit some details of my experiments:

Nitrogen.—Nitrogen, pure and dry, compressed by about 200 atmospheres at a temperature of + 13°, then suddenly set free, is condensed in the neatest manner. There is first formed a material like a pulverized liquid, in drops of an appreciable volume; then this liquid gradually disappears from the walls towards the centre of the tube, forming a sort of vertical column in the very axis of the tube. The total duration of the phenomenon is about three seconds.

These appearances leave no doubt as to the true character of the phenomenon. I first made the experiment at home, at a temperature of — 29°, and I repeated it yesterday, Dec. 30th, a large number of times, in the laboratory of the Normal School, in the presence of many savants and members of the Academy, among whom I am happy to name, with his permission, the honored M. Boussingault.

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[1] *Comptes Rendus*, Dec. 31st, 1877.

Hydrogen.—Hydrogen has always been regarded as the most incoercible gas, because of its small density and the nearly complete agreement of its mechanical properties with those of perfect gases. It was, therefore, only with an extreme distrust of the result, that I decided to submit it to the same ordeals as determined the liquefaction of all the other gases.

In my first attempts I noticed nothing peculiar; but as often happens in the experimental sciences, the habit of observing phenomena ends in causing their signs to be recognized, in conditions under which they at first passed unnoticed. This was the case with hydrogen. In repeating the experiment, this very day, before MM. Berthelot, H. Sainte-Claire Deville, and Mascart, who authorize me to invoke their testimony, I observed indications of the liquefaction of hydrogen, under conditions of evidence which did not appear doubtful to any of the learned witnesses. The experiment was repeated many times. In operating with pure hydrogen, under a pressure of about 280 atmospheres, then suddenly set free, we saw the formation of an exceedingly fine and subtle mist, suspended in the whole length of the gas, and which suddenly disappeared. The production of this mist, notwithstanding its extreme subtlety, appeared incontestable to all the savants who saw the experiment to-day, and who took care to have it often repeated, in such ways as to leave no doubt of its reality.

Air.—Having liquefied nitrogen and oxygen, the liquefaction of air followed as a matter of course; but I thought it would be interesting to make a direct experiment, which, as might have been expected, succeeded perfectly. The air was first dried, and deprived of carbonic acid. Complete confirmation has thus been given to the accuracy of the views expressed by the founder of modern chemistry, Lavoisier, upon the possibility of reducing air to a state of liquidity, thereby producing materials endowed with new and unknown properties, views recalled so pertinently, at the last meeting, by our illustrious perpetual Secretary.

I beg, in conclusion, to express my deep thankfulness to M. Berthelot, and to my dear master, M. H. Sainte-Claire Deville, for all the encouragement that they have kindly given me, as well as for the generous hospitality which has always been shown me in the laboratory of the Normal School.

Liquefaction of NO_2.—M. Cailletet has succeeded in destroying the distinction between coercible and non-coercible gases. He has liquefied nitric acid gas, under a pressure of 104 atmospheres, by keeping the temperature at $-11°$. At $+8°$ the gaseous form is retained under a pressure of 270 atmospheres. Pure formene (CH_4), under a pressure of 180 atmospheres, at 7°, produces a mist, when the pressure is suddenly relieved, like that which arises when there is a sudden diminution of pressure upon liquid carbonic acid. This phenomenon leads him to hope for success in liquefying formene. Berthelot considers this discovery remarkably important, because it advances chemical physics beyond the limit which was reached by Faraday fifty years ago. Hitherto, none of the gases which followed closely Mariotte's law, have been liquefied, notwithstanding repeated attempts by most skilful experimenters. He has himself pushed the compression of some of those gases to about 800 atmospheres, but without success. Within a few years, Andrews has shown the reason for this failure, by showing that every vapor has a *critical point* of temperature, above which it cannot be reduced to the liquid form by any pressure, be it ever so great. Cailletet's experiments show that this critical point, for nitric acid gas, is between $+8°$ and $-11°$. Berthelot thinks it probable that most of the gases which have not yet been liquefied, such as oxygen and carbonic oxide, will succumb to the new processes which Cailletet has so happily inaugurated.—*Comptes Rendus.* C.

Free Acids in the Gastric Juice.—M. Charles Richet finds in the gastric juice only mineral acids or their analogues. When mixed with food, organic acids, analogous to lactic acid, are always found, but the mineral acid predominates until putrefaction begins. The ferment, which acidifies the alimentary materials, seems to be partly retained with the solid portions, and partly removed with the dissolved portions.—*Acad. des Sci.; Les Mondes.* C.

A New Anæsthetic.—Ch. Morel, having found that carbon tetrachloride is less liable to change than chloroform, experimented with it in the laboratory of Paul Bert; when pure it was a perfect anæsthetic, more energetic than chloroform, with an action perfectly regular. He regards it as superior to any other known anæsthetic. He describes his mode of preparation, which is a modification of that of MM. Müller and Crumps, giving better results.—*C. R.* C.

Jute Tissues.—By using jute with other textile fibres, and by employing, at the time of printing, a special distribution of colors, properly shaded, M. Jacobs obtains light-effects, which are very novel and of great brilliancy. On smooth fabrics he produces imitations of velvet in striking relief. The tissues are specially designed for decoration and furnishing, and for these purposes they offer great advantages.—*Soc. d'Enc. pour l'Ind. Nat.* C.

Determination of Longitude.—M. Faye lately addressed the French Academy, in commendation of Lœwy's method for facilitating the calculation of lunar occultations of stars. They furnish one of the best methods for finding terrestrial longitudes, but the work has hitherto been so tedious that few navigators have undertaken it. Lœwy has also prepared new tables, by which one can find the latitude of a place in two minutes, from a single observation of the polar star. C.

Specific Heat under Constant Pressure and Constant Volume.—H. Kayser has investigated the ratio between the specific heats of air under constant pressure and under constant volume, by means of experiments upon the velocity of sound in tubes. His final result is: $K = 1{\cdot}4106$. The previous estimates which he quotes are: Masson, 1·419; Weissbach, 1·4025; Cazin, 1·41; Röntgen, 1·405. [The theoretical value, based on synchronous vibrations, is 1·4232.]—*Pogg. Ann.* C.

New Carbon Battery.—M. Jablochkoff melts nitrate of potash or nitrate of soda, in which he plunges ordinary coke carbon as the active plate, and platinum as the inactive plate. Iron, or any other metal which, in presence of the carbon, is not attacked by the melted salt, may be substituted for the platinum. By adding different metallic salts, the electromotive force of the battery may be varied between 2 and 3 units; it is, therefore, superior to that of the Bunsen and Grenet batteries. The galvano-plastic deposits of the metals may be received at the inactive electrode. During the action of the battery there is a great liberation of carbonic acid and other gases. M. Jablochkoff describes an arrangement for collecting them, so that the combustion of the carbon may give simultaneously an electric current, a metallic deposit, and a motive force.—*Comptes Rendus.* C

Pliocene Man.—At the meeting of the American Philosophical Society, Jan. 18th, Prof. Cope announced the receipt of a collection of fossils from a Pliocene lake-bed in Oregon. In the deposits, in undistinguishable relation with known pliocene fossils, were found numerous flakes, with arrow and spear heads, of obsidian, many of them much tarnished by long erosion. All were lying mingled together on the surface of a bed of clay, which was covered by a deposit of "volcanic sand and ashes" of from fifteen to twenty feet in depth. This had been drifted away by the wind in some localities, thus exposing the remains. C.

Specific Heat of Vapors.—Eilhard Wiedemann has supplemented Regnault's and Winkelmann's investigations, of the specific heats of vapors and their changes with temperature, by some experiments of his own. The comparative results between corresponding temperature-limits, are:

	Regnault.	Wiedemann.
Chloroform, ...	·1567	·1573
Bromide of Ethyl, . . .	·1896	·1841
Benzine, ...	·3754	·3946
Acetone, ...	·4125	·3946
Acetic Ether, ...	·4008	·4190
Ether, ...	·4797	·4943

The differences range between one-third per cent. and five per cent.—*Pogg. Ann.* C.

The Tay Bridge.—The longest railroad bridge in the world, built by the North British railway over the river Tay, at Dundee, was opened to traffic on the 25th of September, 1877. The river at this point is over 3 kilometres wide, and is navigated by ships, so that the permission for the bridge was accompanied by the requirement that it should be high enough to allow the passage of vessels. This required that the middle span should be 26·84 metres above high-water level. The whole length of the bridge is 3173 metres. The foundations of the piers were laid in iron caissons, with compressed air. The piers themselves are partly stone and partly iron. The bridge-beams, some of which weighed 190 tons, were lifted into place by hydraulic pressure. The work was repeatedly interrupted and damaged by severe storms, which occasioned the loss of many lives. Two Gramme machines were employed for night-work, with two Serrin lamps of 1000 candle-power.—*Dingler's Jour.* C.

Aroma of Butter.—A Silesian farmer suspends in his empty churn a calico bag, filled with fragrant herbs, keeping the churn carefully closed. At churning-time he substitutes four smaller bags, attaching one to each of the beaters of the churn. He thus communicates to the butter an aroma as delicate as if the cows had pastured in meadows most highly favored by nature.—*Science pour tous.* C.

New Single Liquid Battery.—M. T. Jourdan has sent to the French Academy a description of a new electric battery. The plates are zinc and plumbago; the liquid is a solution in water of the mixture, known to druggists as *sel de verre* or *fiel de verre* (unvitrified salt). He claims that it is more powerful than a Bunsen battery of the same dimensions, and that the constancy of the current is remarkable. C.

Wolff's Piano Improvement.—M. Wolff adds a third pedal, working a simple mechanism which allows the strings to prolong their notes, or subjects them at once to the action of the damper, at the will of the player. The control is increased by a small register, like those of an organ, representing an octave of which the keys command the mechanism of all the notes, and which is placed within reach of the left hand.—*Soc. d'Enc. pour l'Ind. Nat.* C.

RUHMKORFF.

We regret to record the sudden death, on December 20th, at Paris, of Henry Daniel Ruhmkorff, whose name is so closely connected with the history of magneto-electricity. He was born in Hanover, Germany, in 1803, and but little is known of his early life. In 1819 he wandered to Paris, and obtained a position as porter in the laboratory of Prof. Charles Chevalier, at that time one of the leading French physicists. Here he displayed a remarkable fondness for electrical apparatus, as well as ingenuity in its arrangement, and was enabled shortly after to start a modest manufactory of physical apparatus. Through the efforts of Chevalier, and the excellence of the work performed, the business was rapidly extended. In 1844, Ruhmkorff brought out his first invention, a convenient thermo-electric battery.

Soon after he turned his attention to magneto-electricity, especially the production of the induced currents, discovered by Faraday, in 1832. A long series of experiments resulted in the appearance, in 1851, of the famous "Ruhmkorff coil," with its later modifications, the most important piece of apparatus in this branch of physics. With this powerful adjunct the electrician was enabled to obtain sparks 18 inches in length, pierce thick plates of glass, and carry out a vast variety of experiments. The invention was rewarded by a decoration and medal at the Exhibition of 1855, while in 1858 it received the first prize of 50,000 francs at the French Exhibition of Electrical Apparatus. Since then the manufacture of the coils and of electrical machines in general, has assumed enormous dimensions, and the leading physicists of Europe are well acquainted with the dingy little bureau in the Rue Champollion, near the University. Personally, M. Ruhmkorff was of a quiet, dignified appearance, and despite the disadvantages of his early life, he enjoyed the friendship of the leading Parisian *savants*, and was an honored member of the French Physical Society. M. Jamin delivered an address over the grave, in which he stated that Ruhmkorff died almost a poor man, because he had spent all his earnings on behalf of science and in works of benevolence.—*Nature.*

Book Notice.

A GUIDE TO THE DETERMINATION OF ROCKS.—By Dr. Ed. Jannettaz. Translated from the French by Geo. W. Plympton, C. E., A. M. D. Van Nostrand, 1877.

This is a practical work intended as an introduction to the study of Lithology, and to furnish data for determining rocks by physical characteristics and simple blow-pipe and chemical tests, and as such it is of no little value; but the task undertaken is too great for the brevity of this work. The minerals composing, and commonly contained in, the rocks are dismissed in fifteen pages; the descriptions are good, but, necessarily, too brief; the description of the rocks themselves covers but eighty pages, the rest of the work being devoted to tables for the determination of the rocks. In this small space, however, a great deal of information is given. It is to be

regretted that the book was not subjected to more careful supervision before going to press, and some, at least, of the palpable errors, such as the following, corrected:

P. 26, Micas. The laminæ are *flexible* and elastic.
P. 27. Muscovite Micas, very *rich* in *Magnesia.*
P. 29, Talc and Steatite. Silica about 62 per cent., Magnesia 32 to 33 per cent., Water 48 per cent.
* * The *base* is cleavable.
P. 58. The Basalts of the County of Antrim, Ireland, contain Sulphate of Copper in solution, and owe this property, without doubt, to metallic iron intimately mixed.
P. 85. Sulphates of Iron and Alumina used as fertilizers.

A very objectionable feature of the work is the insertion of a great number of advertisements, occupying one-fifth of the book, and throwing the index in a position not easy of reference. If purchasers of books must pay for so large an amount of matter not pertinent to the subject, we think all would prefer it in a separate volume. R.

Franklin Institute.

Hall of the Institute, Jan. 16th, 1878.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 128 members and 6 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 10 persons were elected members of the Institute, and the following donations were made to the Library:

Descriptive and illustrated catalogue of the Pratt and Whitney Co., Hartford, Conn. From the A. O. Granger.

Specifications and Drawings of Patents, U. S. Patent Office, July, 1877. From the Patent Office.

Indian Meteorological Memoirs. Calcutta, 1876.
Report on the Meteorology of India in 1875.
Report of the Vizagapatam and Backergunge Cyclones of Oct., 1876. By J. Elliott. Calcutta, 1877.

Report on the Administration of the Meteorological Department of the Government of India in 1875–76.

From the Meteorological Department of the Government of India.

United States Geological Exploration of the Fortieth Parallel. C. King, Geologist in charge. Vol. 2, Descriptive Geology. Washington, 1877.

Reports of the Chief of Engineers, U. S. A., for 1867, 1869, 1871 to 1873, inclusive.

From the Chief of Engineers, through E. Hiltebrand.

Papers read before the Pi Eta Scientific Society, 1877. From the Society, Troy, N.Y.

Catalogue of the Trustees, Officers and Students of the University of Pennsylvania, 1877–78. 1st Ed. From L. M. Haupt.

On the Dynamical Law of Horse-power of Steam Boilers, by J. W. Nystrom. Philadelphia, 1875. From the Author.

59th Annual Report of the Trustees of the New York State Library for 1876. From the Trustees.

The Metric System, by H. Hamilton. Harrisburg, 1877. From the Author.

The President presented and read the following Annual

Report of the Board of Managers to the Franklin Institute of the State of Pennsylvania, for the Promotion of Arts, for the year 1877.

Your Board of Managers beg respectfully to submit the following Report:

Members.—During the year, 135 persons were elected members of the Institute, and 37 resigned. Of the deaths of our members we have no means of reporting with accuracy; of one, however, we desire to make a record, from the fact of his having joined the Institute at its first meeting in 1824, and continued a contributing member up to the time of his decease in October, 1877. We refer to Mr. George S. Lang, whose name is the fiftieth attached to our constitution; but two members are now living who signed the constitution before Mr. Lang, viz.: Mr. Frederick Fraley, our Treasurer, and Mr. Geo. Gardom. Mr. Lang, at the time he joined the Franklin Institute, was an engraver of considerable reputation; he after-

wards went into the dry goods business on Eighth Street, from which he retired about ten years ago. Recently he spent two years in finishing a large engraving of the "Landing of Columbus," which he had commenced fifty years before, and an impression from the plate was exhibited in the Art Gallery of the Centennial Exposition.

Treasurer's Report.—The Treasurer's Report, which will be read to the Institute this evening, exhibits the following summary:

Receipts.

Balance on hand Jan. 1st, 1877,	$ 992 01
Sale of investment securities,	5,400 00
Receipts from all other sources,	11,986 19
Total,	$18,378 20

Payments.

5 per cent. building loan and interest,	$ 3,273 75
All other payments,	13,294 97
Balance on hand Dec. 31st, 1877,	1,809 48
Total,	$18,378 20

This statement shows a diminution in the permanent capital of the Institute of $1308.78.

Premiums and Medals.—The following premiums and medals were awarded during the year:

Elliott Cresson gold medal to P. H. Dudley, of Cleveland, Ohio, for his Dynograph, for measuring and graphically recording resistances of railway trains.

Scott Legacy premium and medal to George B. Grant, of Boston, for his calculating machine.

Journal of the Institute.—During the earlier portion of the past year, the JOURNAL was, as heretofore, under the control of an editor, assisted by the committee on publication, but since the 1st of April it has been more immediately under the direction of the committee on publication, aided by the Secretary of the Institute. Its cost of publication has been considerably less than for several preceding years, and its subscription list well maintained.

Drawing School.—The attendance at the night drawing school has not been quite so large as during the previous year, owing, it is

believed, to the continued depressed condition of business affecting in a special degree those who would seek that kind of instruction.

Lectures.—The lectures given during the earlier part of the year, from Jan. 2d, to March 20th, which were of the illustrated series, were: by Mr. Henry Whitall, on Astronomy; Mr. A. E. Outerbridge, on Metallurgy and Assaying of Gold and Silver; Prof. Elihu Thomson, on Electricity; Prof. P. E. Chase, on Inventions of the Century, Ornamental Iron Work, and on Ceramics. And those which were of the elementary series were by Prof. Wm. D. Marks, on the First Principles of Dynamics; Prof. Elihu Thomson, on Elementary Chemistry.

Last year the experiment was made, of having two classes of lectures, one of a highly illustrated character, giving popular instruction in the more advanced grades of science, and especially illustrating and fixing in the minds of hearers, the facts treated of in scientific journals; the other class, more elementary and strictly educational in character.

The success attending that effort was sufficient to warrant its repetition this winter; and it is believed that, with the increased facilities now furnished to lecturers, still more satisfactory courses will be given.

The Board of Managers have authorized the purchase of a Dynamo-Electric Machine, which will add greatly to the scope and brilliancy of the illustrated series.

In place of lectures on Mechanics, in the elementary series, there has been substituted a course on Physics, giving a wider scope, and embracing those elementary laws and properties of matter of more general application.

With the view of increasing its usefulness, the admission of non-members to the elementary course is fixed at the nominal price of $1.00 for the sixteen lectures.

Under this arrangement the following lectures were given during November and December:

In the Illustrated Series, by Prof. Houston, on the "Contrasts and Resemblances of Sound and Light."

And in the Elementary Series, by Prof. E. H. Bartley, on Chemistry.

Prof. Houston also gave, gratuitously, an entertaining familiar lecture to the "young folks" during Christmas week.

Phonography.—Two courses of lectures on this subject were given during the year by Mr. D. S. Holman.

The Board feel much satisfaction in the assurance they have of the solid usefulness of the various lectures which have been given during the year, and of the interest manifested in them by the large and increased attendance by the members of the Institute and others.

As one of the important outgrowths of the lectures on Phonography, a section of the Institute has been established under the title of the "Phonetic Shorthand Section of the Institute."

Monthly Meetings of the Institute.—The attendance at the monthly meetings, of members and strangers, has been quite as large during the past year as in any previous one—and many interesting communications, inventions and novelties have been presented and discussed on those occasions.

Library.—The Board were unable to appropriate as large a sum for the use of the Committee on the Library as was expended last year. The Committee on the Library will report what has been done towards its improvement during the year.

By order of the Board,

R. E. ROGERS, *President.*

Report of the Committee on Library.

The Committee respectfully report that they have held monthly meetings, which have been fairly attended by the members.

The Committee requested the appropriation of $2500 for the library during the year, but only the sum of $1500 was found available for this purpose, and this was appropriated, and the amount was expended as follows:

For the purchase of new books, ...	$605 94
For binding books, ...	656 40
For binding British Patents, ...	54 25
For incidental expenses, freight, etc., ...	165 31
	$1481 90

Leaving an unexpended balance of $18 10.

In addition to the above amount expended in cash, there were received books and exchanges, for which the Committee on Publication was credited, to the amount of .	435 00
Making total amount for the improvement of the Library,	$1916 90

The following additions were made to the Library during the year:

Unbound books, donations,	2835
Bound books, donations,	168
Unbound books purchased,	193
Bound books purchased,	139
Exchanges, bound,	250
Books other than exchanges, bound,	388
Books re-bound,	64
Books repaired,	7
Maps donated,	9
Maps purchased,	19
Plans of buildings purchased,	25

The number of bound vols. in Library, Dec. 31st, 1876,	11,966
The number of bound vols. added in 1877,	945
The number of bound vols., Dec. 31st, 1877,	12,911
The number of unbound vols in Library, Dec. 31st, 1877, is estimated at	6,000
Total,	18,911

During the year 1877, books were taken out by 292 members, an increase of 68 over 1876.

The total number of books taken out by members during 1877, was 2112, an increase of 925 over the year 1876, which indicates an increased use of the library, by members, of about 75 per cent.

This number of books taken out may seem small, unless it be remembered that our library is largely composed of works of reference. The very marked increase in the circulation of books is an index of the increased use of the library by members, for consultation.

The subject of completing our set of French Patents, has received the attention of the Committee, and some of the wanting volumes have been purchased, and all those in the library, 111 vols., well bound; and it is expected that the remainder will be purchased and bound out of the appropriation for 1878.

While the funds at the disposal of the Committee are chiefly devoted to the acquisition of the latest and best books upon subjects within the scope of the Institute, we have been mindful of the advantage of completing our sets of several publications containing the original history of science by discoverers and inventors in their own language. As an example, we have just succeeded in com-

pleting our copy of the memoirs of the old French Academy, from 1666 to 1790, by the purchase of two odd volumes of the memoirs, and ten vols. of the indexes.

By order of the Committee.

WM. P. TATHAM, *Chairman.*

Mr. J. B. Knight, representative of the Institute in the Pennsylvania Museum and School of Industrial Art, presented the following report:

In my Report of June 20th last,[1] the hope was expressed that the schools contemplated in the charter would be put in operation before the end of the year, and I now have the satisfaction of reporting that this has been accomplished.

During the summer a special effort was made to raise funds for the maintenance of the schools, which proving satisfactory, the building No. 312 North Broad Street was secured, and fitted up in a manner admirably suited to the wants of both pupils and teachers.

The course of study decided upon consists of instruction in drawing with instruments, covering the ground of plane and descriptive geometry, projective and perspective, and also free-hand drawing, including manipulation with pencil, charcoal and brush, from study of natural objects, casts, architectural details, and objects from the Museum collection. This will be followed by a study of color, and its application and disposition in design, together with the preparation of original designs suitable for practical application.

The class instruction will be supplemented and reinforced by lectures on kindred subjects.

While the course of instruction adopted presents no novelty, it is intended to make the training thorough, so that those availing themselves of its advantages may be well grounded in the principles underlying what is known as design.

The persons selected as instructors are: Mr. Charles M. Burns, in the artistic division of the course, and Mr. Philip Pistor, in the scientific branches; and, as lecturers, Dr. J. T. Rothrock, on Botany as applied to decorative art, and Mr. Geo. Herzog, on Historic Ornament.

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[1] See Vol. civ, page 6, July, 1877.

It having been decided that the instruction shall be free to citizens of the commonwealth, of either sex, it became necessary to adopt a standard of examination that requires a knowledge of the rudiments of drawing on the part of the applicant, and to adopt rules which should demand earnest work of the students, and prevent the classes being filled with incompetent or careless students. This was done with the advice and aid of the instructors, and, out of about 200 applicants, 100 were selected as proficient; and the schools were opened on December 17th, with this number of students, it being the maximum that could be accommodated.

Special classes in art needlework, embroidery and lace-work, have been formed, and Miss Mary Jones Atkinson, from the Royal School of Art Needlework, London, appointed instructor. Tuition in these classes is free to those who are unable to pay, but, to meet the demand for this kind of instruction among persons who were able and willing to pay, a few classes of pay pupils have been formed, and so arranged as not to interfere with the free classes, yet aiding considerably in supporting the schools. The Committee on Instruction has been aided in the organization and management of these classes, by twelve ladies, who have kindly consented to act as an Advisory Committee.

The work of organizing and managing the schools was placed in the hands of the Secretary, Mr. H. Dumont Wagner, under the direction of the Committee on Instruction; and the Trustees speak highly of the manner in which he has performed this as well as his other duties.

It is to be understood that the schools, as now arranged, are but a beginning, to be amplified and extended as circumstances will permit, and if this effort on the part of the trustees meets that support which its importance demands, it must prove of immense value to the industries of the state.

Several valuable and interesting objects have recently been added to the collections, and among those worthy of special mention are the models, in cork, of Windsor Castle and the Tower of London, by Lloyd Hoppin. These were presented by a committee of members.

The number of visitors to the Museum collection in Memorial Hall since the opening, May 10th, 1877, to Jan. 1st, 1878, was 147,113. The Trustees, wishing to give the widest effect to the educational influences of the collections, decided to open them to the public on Sun-

days, and this was done, commencing July 24th, since which time 20,280 persons have visited the Museum.

In the early part of the year the By-Laws were amended in such a manner as to place the active work of the corporation in the hands of an Executive Committee, consisting of thirteen members of the Board, together with the President, Vice-Presidents, Treasurer and Secretary.

An election was held on the 14th inst., with the following result:

President, Coleman Sellers.

Vice-Presidents, Ed. T. Stevens, Wm. Platt Pepper.

Treasurer, Clarence H. Clark.

Secretary, H. D. Wagner.

Executive Committee.—W. H. Merrick, Chapman Biddle, Samuel Wagner, Jr., F. O. Horstmann, W. W. Justice, Thomas Cochran, J. Vaughan Merrick, J. B. Knight, Adam Everly, Wayne McVeagh, T. R. Shelton, J. C. Brown, J. R. Baker.

The Report of the Board of Trustees, giving a history of the corporation, from its organization to Dec. 31st, 1877, will shortly be printed, and then may be had on application at the office, No. 312 North Broad Street.

J. B. Knight.

Mr. Edward R. Andrews, of Boston, Mass., read a paper on creasoting timber, including a description of the Hayford process and apparatus for preserving wood.[1]

The Secretary presented his report, embracing Murphy's Pneumatic Fire Extinguisher, Evarts' Health Lift apparatus, and the Eureka Self-Lighting Gas Burner.

The tellers presented their report of the annual election held this day, which was accepted, and, in accordance therewith, the chair declared the following members elected:

President, R. E. Rogers, M. D.

Vice-President, Chas. S. Close.

Secretary, J. B. Knight.

Treasurer, Frederick Fraley.

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[1] See page 109.

Managers to serve three years, Geo. Burnham, Coleman Sellers, Wm. P. Tatham, Washington Jones, Isaac Norris, Jr., M. D., Jos. M. Wilson, Theo. D. Rand, Pliny E. Chase.

Managers to serve one year, Wm. B. Bement, Prof. Elihu Thomson.

Auditor, James H. Cresson.

Representative to the Pennsylvania Museum and School of Industrial Art, J. B. Knight.

Under the head of deferred business, the proposed amendments to the by-laws, deferred from the last meeting, were taken up.

Mr. Mitchell stated that, in view of the necessity of obtaining the consent of a majority of the stockholders, in order to amend Art. I of the By-Laws, and the consequent expense, and from information he had received since they were offered, he now wished to withdraw the proposed amendments to Sec. 2, Art. I, and Sec. 5, Art. II.

Unanimous consent being given, they were so withdrawn.

The resolution to strike out all of Sec. 7 of Art. II, on being put to vote, was lost.

Mr. Washington Jones then offered the following preambles and resolution, which were adopted:

WHEREAS, It is stated in the public prints that a meeting of the United States Steamboat Inspectors is to be held in the city of Washington, at which the subject of stamping boiler iron will receive prominent consideration, and that a committee of iron manufacturers will be present at the meeting; and

WHEREAS, There exists a difference of opinion amongst boiler makers and users, as to the desirability of employing the grade of iron known as C. H., No. 1 Shell, for the external, not flanged, portions of boilers, instead of that known and stamped C. H., No. 1 Flanged; therefore, be it

Resolved, That the Franklin Institute ask of the U. S. Steamboat Inspectors and boiler plate manufacturers, an investigation and expression of opinion as to the advisability of using the lower grade of iron for shells of boilers, consideration being had to the qualities of tensile strength, ductility, liability to corrosion, and cost.

On motion of Mr. W. Barnett Le Van, it was

Resolved, That Prof. Persifor Frazer, Jr., be requested to repeat his lecture on the Metric System of Weights and Measures, as delivered by him before the Social Science Association; and that the Committee on Meetings be requested to fix a time.

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary*.

THE JOURNAL

OF THE

FRANKLIN INSTITUTE.

Devoted to Science and the Mechanic Arts.

The JOURNAL OF THE FRANKLIN INSTITUTE is issued in monthly numbers, of seventy-two pages each, largely illustrated, forming two volumes annually.

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Beside a great variety of matter of general interest, the JOURNAL contains the proceedings of the meetings, and has contributed in a very large degree to the usefulness of the Institute, which should especially commend it to the support of the members.

The Committee on Publication are desirous of increasing its circulation, being fully assured that it will more than repay the small outlay required to secure it.

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The Franklin Institute is not responsible, as a body, for the statements and opinions advanced by contributors to the Journal.

THE FLOW OF METALS.

By David Townsend.

In investigating the subject of the punching of metals, and the consequent flow which occurs, no exact law could be determined, covering all cases, owing to the limited number of experiments made, and also to the want of technical knowledge on the subject. M. Tresca, in *La Poinçonnage des Métaux*, published some experiments on the punching of iron, but his results cannot be accepted as complete and accurate, owing to the fact that the means at his disposal were limited; those that were arrived at, were for the action of a large diameter of punch upon small thickness of metal. His experiments were made with a punch of 1·18 inches diameter (30 mm.), on iron plates, the greatest thickness being ·669 inch (18 mm.), and the least ·1968 inch (5 mm.). He announced, as the result of his investigations, the general law that "*when pressure is exerted upon the surface of any material, it is transmitted in the interior of the mass from particle to particle, and tends to produce a flow of metal in the direction in which the resistance is least.*"

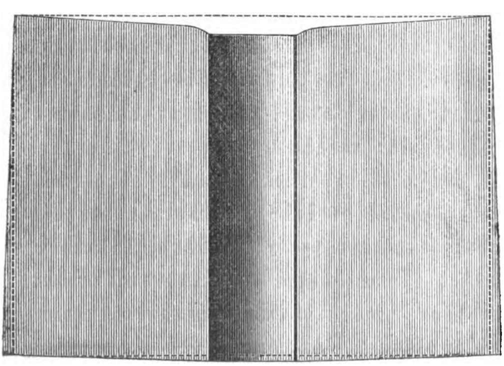
The following experiments were made with nuts, or bars, punched, cold, by Messrs. Hoopes & Townsend, and are intended to show that an actual flow does take place in metals under pressure, which flow is governed by some law not yet enunciated.

The first experiments were made with rectangular blocks of iron, which were planed accurately to the dimensions given in the table below, and then punched, cold, through the centre of the block.

BEFORE PUNCHING.				AFTER PUNCHING.				
	Width.	Thick.	Length.	Width.		Thick.	Length.	
				Top.	Bottom.		Top.	Bottom.
No.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
1	1·745	1·748	2·51	1·775	1·82	1·748	2·511	2·562
2	1·742	1·748	2·51	1·768	1·814	1·748	2·510	2·552

From the above table, it is seen that, as the punch entered, a flow took place, which was greatest in the width—the direction of least resistance—the length being but slightly increased. By comparing the widths at the top and bottom, we see that the increase has been greatest on the bottom face of the block. From this we should conclude that the flow was greatest at the bottom of the piece; but such is not the case, for the block, resting against the immovable bed of the machine, could not curve down as could the metal at the top, and was, therefore, compelled to spread laterally, producing this increased width.

Fig. 1.

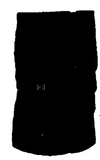


If we examine the punched block, we notice that it has bulged in the width, producing a curved surface, concave towards the axis, greatest at the central line of its width, and decreasing gradually in either direction as it departs from that line.

The length is also increased, but not as noticeably as the width. When the punch first touched the block, the whole upper face was depressed (Fig. 1), the surface converging towards the hole as the lowest point, in the immediate vicinity of which the metal curved sharply downward, like water flowing into an orifice. This depression can be seen in Fig. 1, which is a longitudinal section, the dotted lines being the dimensions of the block before punching, and the black lines, after. We also see that the block has become wedge-shaped, and is slightly convex on the bottom face.

If now we look at Fig. 2, which represents the core punched from the block, we see that it is only $1\frac{1}{16}$ inches in depth, while the hole from which it came was $1\frac{3}{4}$ inches thick. At first sight, it would seem that all the metal from the hole had been squeezed into the core, and, therefore, that its density must be increased directly as this ratio of thicknesses. To prove that such was not the case, a piece of metal was chipped from block No. 1, and its density taken, with the following result:

FIG. 2.



Weight in air, ...	3·78 gms.
" " water, ...	3·297 "
Loss, ...	·483 "

$$\therefore \frac{3{\cdot}78}{{\cdot}483} = 7{\cdot}82 = \text{density of the block.}$$

The core itself was then treated in a similar manner, giving:

Weight in air, ...	14·9965 gms.
" " water, ...	13·07 "
Loss, ...	1·9265 "

$$\therefore \frac{14{\cdot}9965}{1{\cdot}9265} = 7{\cdot}78 = \text{density of the core.}$$

From this it appears that the density of the block is slightly more than that of the core; but this difference is probably due to the density of the surface being increased by chipping and filing, and also to the preponderance of matter in the block over the core. As the density has not increased, there must have been a flow of metal from the core into the block, the amount of which we will now determine.

Three experiments were made with blocks of the same thickness and diameter of hole, and the volumes of the resulting cores were determined by displacement, on account of their being irregular bodies. All the experiments being made with the water at a constant temperature, no correction is necessary for differences of temperature.

Core from block No. 1:

Weight in air, ...	14·9965 gms.
" " water, ...	13·07 "
Loss, ...	1·9265 "

The weight of the water displaced is therefore 1·9265 gms., and is equal in volume to that of the body producing the displacement. As 1 gramme of water exactly equals 1 cubic centimetre, the displaced water has a volume of 1·9265 cubic centimetres, which is also the volume of the core. Now as 1 cubic centimetre = ·06103 cubic inch, the volume of the core in inches is equal to ·11757295 cubic inch. If, now, we take the measurements given in the table, and calculate the volume for a hole of $\frac{7}{16}$ inch in diameter, we find:

V = ·3773294 cubic inch = volume of hole.
V = ·1175743 " " = volume of core.

·2597551 " " = volume of the metal which has flowed into the block from the core in the process of punching; and corresponds to 68·844 per cent.

Core from block No. 2:

Weight in air, ...	14·864 gms.
" " water, ...	12·953 "
Loss, ...	1·911 "

This loss is equal to a volume of ·1166283 cubic inch. The volume of the hole being the same as before, we have:

V = ·3773294 cubic inch.
V = ·1166283 " "

·2607011 " " = volume of metal flowing, which is equal to 69·09 per cent.

The third example was a finished hexagon nut, having the same thickness as before and same diameter of hole.

Core of No. 3:

Weight in air, ...	15·154 gms.
" " water, ...	13·220 "
Loss, ...	1·934 "

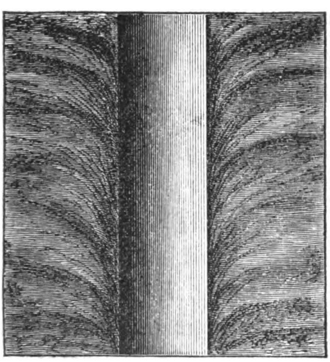
The volume of the core is therefore equal to ·117974 cubic inch, and we get:

$$V = \cdot 3773294 \text{ cubic inch.}$$
$$V = \cdot 1179740 \quad " \quad "$$
$$\cdot 2593554 \quad " \quad " = \text{volume of metal}$$

flowing, or 68·73 per cent.

Similar experiments were tried with other thicknesses; but the flow was not so marked, and seemed to decrease directly as the diameter of the hole increased, and as the thickness of the bar decreased.

Fig. 3.



In order to show to the eye, the flow which had thus occurred, several of the large nuts with their cores were planed in half. The resulting rectangular faces being brightly polished and perfectly clean, were then etched with acids of various strengths, when they presented the appearances of Figs. 3 and 4.

Fig. 4.

The curved lines mark the laminæ, or plates, which were piled and rolled together, to make up the bar. It will be noticed that they all curve downward, and that the greatest curvature occurs at the top, remaining nearly constant for some distance, and then decreasing towards the bottom. This shows that the flow must have occurred when the punch first entered the bar, and was continued regularly, until the pressure above parted the under face, and the core was forced out. If we examine at the core, we find that at the top, where the punch first strikes the block, it is concaved upwards, and that the laminæ composing it are forced

in curved layers before the punch, until the resistance of the lowest part of the metal was overcome, when we find that the curves get more and more flat, until at the bottom face there is a slight concavity, due to the flow which took place through the opening in the die.

In the case represented in Figs. 5 and 6, the hole was punched *with* the grain, instead of *across* it, the result being that the superposed laminæ, instead of being curved downward,

Fig. 5.

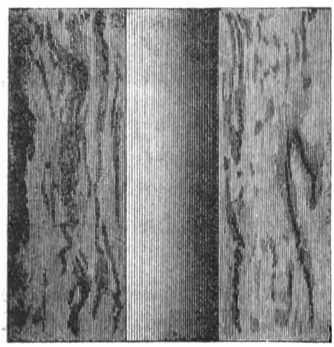
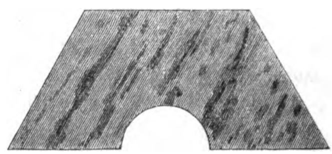


Fig. 6.



were wrinkled or warped, from the flow and the consequent pressure which took place, acting against their sides or faces.

Acting on suggestions obtained from the above results, several experiments were tried by partially punching bars of the same thickness with punches that had the same diameter, but which varied in length according to the depth of the hole to be punched. The bars were uniformly $1\frac{13}{16}$ inches thick, and the punch $\frac{7}{16}$ inch in diameter; the following were the results obtained:

1. The first bar was punched to a depth of exactly $\frac{7}{8}$ of an inch; the resulting piece was then planed in half, polished, and etched with acid, when its surface had the appearance of Fig. 7. Here we see that, although the punch has gone half way through the bar, it has hardly marked the under surface. If we observe the lower portion of Fig. 7, we see that some of the layers have not yet been bent out of shape, and, therefore, that the marking of the under surface could not have been due to the flow or to the starting of the core, but was caused by the general pressure of the punch on the body of the metal over the hole in the die.

2. The next bar was punched to a depth of $1\frac{1}{8}$ inches, and on being treated with acid, as before, it showed the form of Fig. 8. We find that the mark on the under face now projects $\frac{1}{16}$ of an inch, and

that the lowest layers are slightly disturbed; therefore, the point of maximum flow has been reached, and must lie between $\frac{7}{8}$ inch and $1\frac{1}{8}$ inches in depth, or, in other words, the starting point of the core, for the above thickness of iron, is about 1 inch from the upper surface of the bar.

3. In the third experiment, under exactly the same conditions, the punch was entered into the bar to a depth of $1\frac{1}{4}$ inches. Referring to Fig. 9, we see that here the core has started, and is projecting $\frac{1}{8}$ of an inch below the under face of the block. The layers are all bent, the lower ones being the least, and the upper ones, where the punch has passed, showing the flow, as in the case of complete punching represented in Fig. 3. We also see that the core has already

Fig. 7.

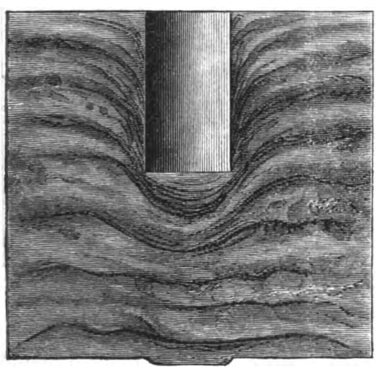
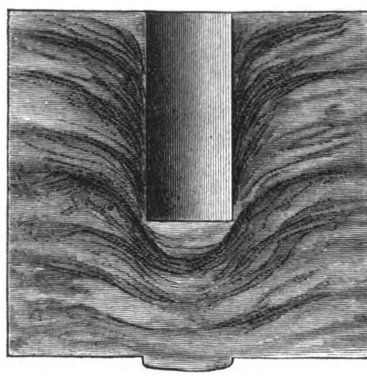


Fig. 8.



attained its least thickness, being but $\frac{3}{4}$ of an inch in depth, which is about that of the core represented in Fig. 4.

4. In the fourth and last experiment, the punch was stopped at a depth of $1\frac{1}{2}$ inches, the resulting block being shown in Fig. 10. The core projects from the bottom face nearly $\frac{1}{2}$ inch, and measures, as before, almost $\frac{3}{4}$ inch in depth. The layers, in this case, are all severed, and the line of parting of the core from the block is plainly visible. The force necessary to finish the punching is very small, compared to the total force required to punch such thickness of metal. The point of the maximum flow of metal is visible to the eye when watching the action of the machine, which gives a slight jar,

starting downwards, as if relieved from great pressure, when the core just starts, or wholly divides the under surface of the block.

That these experiments prove the flow of metal to occur in cold punching, and at great depths, is undeniable, but whether it will in the future be practically applied to take the place of partial drilling, is a matter which time only can determine.

This property of flowing in downward curves is highly advantageous to the quality of the nut, as, on being tapped, the thread is made up of several layers, instead of one, and the strain which comes on them is taken on end instead of across the grain, thus giving the iron

Fig. 9.

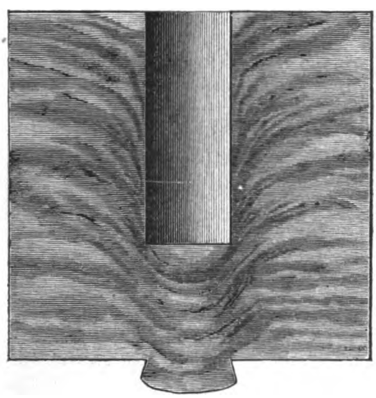
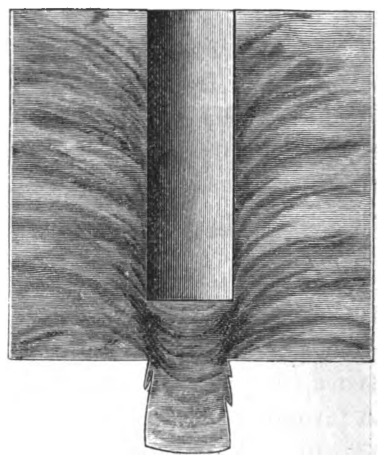


Fig. 10.



a much greater resisting power. The process of punching these thick bars does not depend for its successful performance upon the time taken, but upon the accuracy and power of the machine, and the quality of the punch. The element of time is introduced only so far as the wear and tear of the tools and the machinery determine it; as for the flow, that remains the same, whether the motion is fast or slow.

Stevens Institute of Technology,

Hoboken, N. J., Jan., 1878.

RADIATION OF HEAT FROM STEAM-BOILERS, PIPES, ETC.

By Chief Engineer ISHERWOOD, U. S. Navy.

Experiments made at the "Vulcan Works," Baltimore, Md., to ascertain the law governing the loss of heat by radiation from the plate iron surfaces of steam-boilers, steam-pipes, etc., in function of difference of temperature between that of the internal steam and that of the external still air. Also, the quantity of heat in Fahrenheit units thus radiated per hour per square foot of surface per degree Fahrenheit difference of temperature on the opposite sides of the naked metal. Likewise, to ascertain the decrease that may be effected of this radiation by clothing the metal with hair-felt of different thicknesses.

The experiments hereinafter described were made in 1863, 1864, and 1865, by the writer, who, being at that time the Chief of the Bureau of Steam Engineering in the Navy Department, had the designing and repairing of the machinery of most of the enormous number of steamers belonging to the United States Navy during the war of secession. Among the items of expense, the cost of hair-felt for covering boilers was very great, and he instituted these experiments for the purpose of discovering the most profitable thickness of felt to be employed; that is to say, the thickness, whose cost, taken in connection with the cost of the fuel it could save during the time it lasted, would be a minimum.

A favorable opportunity for making the experiments occurred at the "Vulcan Works," in the City of Baltimore, where the repairs of the machinery of the North Atlantic Fleet were principally made, and where a staff of expert naval engineers was constantly employed. The writer having constructed the apparatus and organized the experiments, all that the engineers had to do was to conduct them accordingly, and fill up the columns of a printed log or tabular record, furnished them, with the quantities observed. These logs were forwarded to the writer at the close of each experiment, and from them he generalized the following results:

In steam engineering it is of considerable importance to know the quantity of heat radiated from the external surfaces of steam-boilers, steam-pipes, etc., both when naked and when clad with hair-felt, the latter being the usual non-conductor employed to diminish the escape of the heat. The quantity of heat thus lost by the radia-

tion from the naked metal, will evidently be, *ceteris paribus*, directly as the extent of surface exposed, and as some function of the difference between the temperature within the boiler or pipe and that of the air surrounding it; and, when the metal is covered, this quantity will be diminished in some function of the thickness of the enveloping felt. The object of the following experiments, therefore, was to ascertain these two facts for the mean conditions of ordinary steam-engineering practice.

The metal selected was plate iron of the average kind used in boiler making, and having a thickness of five-sixteenths of an inch. The experiments were first directed to ascertain the number of Fahrenheit units of heat radiated per hour in still air, from a square foot of the naked metal per degree Fahrenheit difference of temperature on its opposite sides, for different intervals of temperature thereon; and, afterward, to ascertain, in an exactly similar manner, the number of Fahrenheit units of heat radiated per hour in still air per degree Fahrenheit difference of temperature between that of the steam within the boiler or pipe and that of the still air surrounding it, for different intervals of these temperatures, from a square foot of the metal covered with different thicknesses of hair-felt.

The experiments were made by means of the apparatus described below, and in the manner thereafter narrated.

Description of the Apparatus.

The radiator consisted of a rectangular box, made of the ordinary plate iron used for boilers, and five-sixteenths of an inch in thickness. The interior dimensions of its sides were 72 inches long and 36 inches wide. It was 2 inches broad on the interior, and its sides were braced square across every 9 inches, by the ordinary $\frac{7}{8}$ of an inch diameter socket bolts employed for bracing the flat water-spaces of boilers. Each side was composed of a single plate, and the box was formed by riveting the plates together. The interior superficies of the box was 39 square feet, and the exterior superficies was 40·926 square feet, the ratio of the two superficies being respectively as 1·0000000 to 1·0493846. The inner capacity of the box was 3 cubic feet. These measurements are for the temperature of 60 degrees Fahrenheit.

The radiator was placed on wooden supports, with one of the diagonals of its sides vertical, so that the upper corner of the box

formed an apex, and the diagonally opposite lower corner formed a point of lower depression than any other in the box. In this position its apex communicated by a steam-pipe of 2 inches outside diameter, with the upper portion of the steam-drum of the boiler furnishing steam for the engine of the "Vulcan Works." The apex of the box was placed 3 feet in height above the top of the steam-drum, so that any water of condensation formed in the steam-pipe would, by draining back to the boiler, by gravity, be prevented from entering the radiator. To render the quantity of such water of condensation a minimum, the steam-pipe was permanently covered with hair-felt 4½ inches thick. In the steam-pipe, and as close to the radiator as possible, was placed a stop-cock to be used as a throttle-valve to control the admission of the steam to the radiator, and maintain it therein at any desired pressure, not exceeding that in the boiler. On one side of the radiator, and just below its apex, was placed a carefully tested spring-gauge, to indicate the pressure of the steam within the radiator.

From the point of lowest depression of the box, proceeded a leaden pipe of one inch outside diameter, which was coiled into a tank through which passed continuously a stream of cold water drawn from the pipes of the city water-works. By properly regulating the quantity of cold water passing through the tank, the water of condensation from the radiator traversing the coil of pipe, could be delivered at about the temperature of the atmosphere into the closed vessel provided to receive it, and in which it was carefully weighed at regular intervals. By means of this arrangement, as little of the water of condensation as possible was lost by evaporation into the atmosphere. A stop-cock was placed in the leaden pipe as near the radiator as possible, to control the delivery of the water of condensation, and prevent the escape of any steam. A vertical glass water-gauge, one end of which communicated with the side of the radiator at its lowest point, while the other communicated with that side 18 inches higher, constantly denoted the water level within the radiator, which was kept at the lowest point possible without risking the escape of steam.

Although the radiator was placed in the still air of a large enclosed shed, yet it was not in confined air, as the shed had many and large openings, so that the air set in motion by the heat received from the radiator, could pass off and be renewed without restriction. And to

shield the radiator from all air currents otherwise caused, and from all accessions of heat externally, it was enclosed by wooden partitions, open above and below. The air had thus free ingress and egress around the radiator, but with no greater velocity than due to its heating by the radiator. The purpose of the entire arrangement was to place the radiator as nearly as practicable in the same surroundings as steam-boilers have in the holds of vessels. The temperature of the inflowing air was taken by two thermometers, hung outside of the partitions, and its pressure was taken by a barometer.

The covering employed was the ordinary cow hair-felt, manufactured for clothing steam-boilers, weighing one pound per square foot, when 1½ inches thick. It was stitched tightly over the radiator, so as to be in contact at all points, thereby preventing air-spaces, or air circulation, between the felt and the radiator. The thickness of the felt experimented with, was ¼ inch, ½ inch, ¾ inch, 1 inch, 2 inches, 3 inches, 4½ inches, 6 inches, and 7½ inches.

Manner of making the Experiments.

The steam with which the radiator was supplied, was drawn from the boiler of the "Vulcan Works," a sufficient pressure being kept in it for that purpose while the works were not in operation.

Each experiment continued 72 consecutive hours, during which exactly the desired steam-pressure was maintained in the radiator by an assistant engineer, who watched the steam-gauge and regulated by hand the throttling-cock in the steam-pipe to produce that effect. Enough water being at the same time passed through the refrigerating tank from the pipes of the city water-works, to reduce the temperature of the water of condensation discharged from the radiator to about that of the atmosphere. After the conditions were made uniform, the apparatus, in order that every portion might become in harmony with them, was operated for an hour before the experiment was held to commence.

For each experiment a tabular record was kept, in which were entered at the end of each hour the temperature of the air as given by the mean of the two thermometers, and the height of the barometer. The weight of the water of condensation was also entered at each time of weighing. Every care was taken to secure accuracy in the instruments used, and in their use. The boiler-pressure being limited to 65 pounds per square inch above the atmosphere, the

highest pressure used in the radiator was 60 pounds; the other pressures used therein were 50 pounds, 40 pounds, 30 pounds, 20 pounds, and 10 pounds per square inch above the atmosphere. The experiments were thus made for regular differences of 10 pounds per square inch in the pressure of the steam; and each set of experiments was six in number.

With the radiator naked, four sets of experiments were made, each set being an exact repetition of the others, so that the aggregate duration of the four experiments, with steam of 10 pounds pressure per square inch above the atmosphere, was 288 hours; of the four with 20 pounds pressure, 288 hours, and so on of the rest, each pressure being experimented with during 288 hours, making a total of 1728 hours with the naked radiator.

With the radiator covered with hair-felt ¼ of an inch thick, one set of six experiments was made with steam of respectively 10, 20, 30, 40, 50, and 60 pounds pressure per square inch above the atmosphere; the aggregate duration being 432 hours. And precisely the same number of experiments were made, and with the same steam-pressures, with the radiator covered with hair-felt of ½ and of ¾ inch thickness; the aggregate duration of these experiments with each thickness being 432 hours.

When the radiator was covered with hair-felt of 1 inch thickness, two sets of six experiments each were made, the one set a duplicate of the other, the same steam-pressures of 10, 20, 30, 40, 50, and 60 pounds per square inch above the atmosphere being used in each, making the aggregate duration 364 hours.

With the radiator covered with hair-felt of respectively 2, 3, 4½, 6, and 7½ inches thickness, one set of six experiments was made with each thickness; the same steam-pressures of 10, 20, 30, 40, 50, and 60 pounds per square inch above the atmosphere being used with each thickness. The aggregate duration of the experiments with each thickness was 432 hours.

There were thus made in all 84 experiments, extending in the aggregate through 6048 hours.

Determination of the Results.

In ascertaining the number of Fahrenheit units of heat radiated per square foot of surface, the interior dimensions of the box or radiator were used, and these dimensions were calculated for each

difference of temperature, as the temperature varied in each experiment; that is to say, the temperature of the interior superficies of the box was assumed to be the same as that of the contained steam, and its dimensions, at the standard temperature of 60 degrees Fahrenheit, were increased by the amount of the dilatation due to the temperature of the steam within. The temperature of the steam normal to the experimental pressure, was taken from Regnault's experiments. The effect of the barometric variation was also included in the calculations, the number of units of heat radiated being corrected to what they would have been, had the pressure of the air been equal to the standard of 29·92 inches of mercury, at 32 degrees Fahrenheit. This correction was made in the direct ratio of the density of the air.

The number of units of heat radiated during each experiment, was calculated, with the above corrections, from the weight of the water of condensation discharged from the radiator, and from the latent heat of steam of the experimental pressure, being simply the product of these two factors. As the steam-pressure varied in the different experiments, and as the latent heat varies with the pressure, it was necessary to substitute the number of units of heat radiated in equal time for the pounds weight of steam condensed during that time, as the measure of the radiation; consequently, for each experiment these units were separately calculated per square foot of radiating surface and per hour, and these quantities being divided by the difference between the Fahrenheit temperature of the steam inside the radiator and that of the air outside, gave the final result in number of Fahrenheit units of heat radiated per square foot of surface per hour per degree Fahrenheit difference of temperature on the opposite sides of the radiating surface.

The extremely near equality of these final results given by each set of the different experiments under very considerable inequality of condition, shows at a glance that, *ceteris paribus*, within the limits of the experimental temperatures, *the quantity of heat radiated in equal time from the same surface with different temperatures on its opposite sides, was in the direct ratio of their difference.*

A straight line being taken for a base, and divided by scale into abscissæ, corresponding in lengths to the different thicknesses of hair-felt with which the radiating surface was covered, and from the end of each abscissæ a perpendicular being erected on which was laid off by scale, as an ordinate, the mean final result for each set of

experiments in Fahrenheit units of heat radiated per hour per square foot of surface per degree Fahrenheit difference of temperature on the opposite sides of the surface, a graphic curve, passed through the free ends of these ordinates, was found to be such that it coincided almost exactly with the law that the number of units of heat radiated was in the inverse ratio of the square roots of the thicknesses of felt employed from the thickness of $7\frac{1}{2}$ inches up to the thickness of 1 inch, from which latter thickness up to the naked metal, the curve, though a fair one, followed no regular law. A curve laid out on the same scale, with the ordinates proportional to the square roots of the abscissæ, scarcely varied the thickness of a pencil-line from the graphic curve obtained as above described for the experiments with felt of various thicknesses between $7\frac{1}{2}$ inches and 1 inch.

The term "radiation" has thus far been applied for the sake of convenience to the process by which the heat left the surface, but in fact the heat escaped by means of two entirely distinct processes, acting independently of each other, and simultaneously, the one radiation proper, the other conduction. By means of the first, a certain portion of the escaping heat was radiated through the air heating it to only an insensible degree, while by means of the last, the remaining portion of the escaping heat was transferred by conduction from the hot metallic surface to the particles of cool air resting upon it, which, as soon as heated by the contact, were pushed out of place by other particles of cool air, to be in their turn heated and displaced, the movement being a result of the lessened density of the air after it is heated. Part of the escaping heat was thus taken up by the air, and the remainder by the distant bodies on which the radiant heat impinged These remarks apply in their integrity to the case of the naked metal alone, but when the metal is covered with hair-felt, only the hairs of which, considered separately, have any conducting power, the interstitial air being sensibly destitute of that quality; and where it is considered that by the process of felting short hairs are merely loosely interlaced, touching each other only at a few points, whereby those on the exterior surface can be scarcely said to have any connection with those on the interior surface, which latter alone are in contact with the metal, and receive heat from it by conduction; it will be seen how very little heat can be transferred from the metal to the outside hairs by the conducting power of the hairs themselves. Whatever increase of temperature, therefore, the

outside hairs receive, is not from the metal, which they do not touch, but from the air by which they are surrounded, and which has been heated by conduction; consequently, almost all the heat lost by the metal has gone in the first instance to heat the interstitial air by conduction, a merely infinitesimally small portion being expended upon the hairs by conduction, and by them radiated through the atmosphere to the nearest objects.

Thus, in the case of the metal having a hair-felt covering, sensibly the entire loss of heat is by conduction alone, and is expended in heating the interstitial air. The quantity of such air heated in a given time, will depend on the rapidity with which it can be replaced, and that rapidity is evidently a function of the thickness of the felt; for the velocity with which the heated air is expelled from the interstices by the greater density of the outside cool air, will be regulated by the number of hairs or resistances which impede the movement, and this number will be directly as the thickness of the felt. Now, as soon as uniformity of movement is established in the heated interstitial air, the pressure causing it and due to the greater density of the outside cool air, will remain constant, and as with constant pressure the velocity of air moving against different resistances is inversely as the square roots of those resistances, that velocity, in the case of our problem, will consequently be inversely as the square roots of the number of opposing hairs, or inversely as the square roots of the thickness of the felt. And as the quantity of heat carried off from the metal by the interstitial air in equal time, is measured directly, *ceteris paribus*, by the velocity with which that air moves over the metallic surface, *the quantity of heat lost in equal times by the metal*, ceteris paribus, *when covered with different thicknesses of felt, will be inversely in the ratio of the square roots of these thicknesses.* Such is the ratio which was experimentally found to exist for all thicknesses of felt over one inch, but for thicknesses of less than one inch the experimental ratio was higher, the loss of heat with such small thicknesses being greater than inversely in the proportion of the square root of the thickness. This was doubtless owing to the fact that a thickness of one inch was required to accumulate a sufficient number of hairs to completely intercept the radiant heat proceeding from the metal, less thicknesses allowing an escape of heat by direct radiation through the interstices, as well as by the conduction of the interstitial air. The experiments, then, not

Table 1.

Showing the loss of heat per hour in Fahrenheit units,[1] per degree Fahrenheit difference of temperature between the temperature of the steam upon one side of a square foot of boiler-plate iron 5-16 of an inch thick, and the temperature of the still air upon the other side, when naked, and when covered on the air side with different thicknesses of cow-hair felt weighing one pound per square foot for the thickness of $1\frac{1}{2}$ inches:

Thickness in inches of the cow-hair felt on the air side of the boiler-plate iron.	Number of Fahrenheit units[1] of heat lost per hour per square foot of boiler-plate iron 5-16 of an inch thick, per degree Fahrenheit difference of temperature between that of the steam on one side of the metal, and that of the still air upon the opposite side.	Thickness in inches of the cow-hair felt on the air side of the boiler-plate iron.	Number of Fahrenheit units[1] of heat lost per hour per square foot of boiler-plate iron 5-16 of an inch thick, per degree Fahrenheit difference of temperature between that of the steam on one side of the metal and that of the still air upon the opposite side.
Naked.	2·933067200000000	4·00	0·153527736250000
0·25	1·054071025000000	4·25	0·148499160098979
0·50	0·572864687500000	4·50	0·144747361312670
0·75	0·412462575000000	4·75	0·141307301065023
1·00	0·307055472500000	5·00	0·137319380496593
1·25	0·274638760921693	5·25	0·134089991829888
1·50	0·250709717124564	5·50	0·130918876690775
1·75	0·232112059255524	5·75	0·128050971134813
2·00	0·217120939617333	6·00	0·125325955324240
2·25	0·204703648333028	6·25	0·122822189000000
2·50	0·194198911355266	6·50	0·120437220476490
2·75	0·185161460871052	6·75	0·118185716224532
3·00	0·177278540008271	7·00	0·116056073492882
3·25	0·170323696621130	7·25	0·114037556701880
3·50	0·164128026933513	7·50	0·112120797096856
3·75	0·158546362813801		

[1] The Fahrenheit unit of heat is the quantity of heat required to raise the temperature of one pound of water at 32 degrees on Fahrenheit's scale to 33 degrees.

only give the loss of heat quantitatively due to the different thicknesses of the felt, but furnish likewise the physical proof of the theoretical law regulating that loss in function of the thickness of the felt.

The figures in Table No. 1 show, by mere inspection, the *relative* loss of heat when the metal is naked, and when it is covered with felt of different thicknesses, *for the same steam-pressure and for the same air-temperature.* But they can also be employed to determine, in any given case, the absolute quantity of heat lost for any pressure of steam and temperature of air. For example: Suppose a naked boiler, the surface of whose shell is 450 square feet, the air temperature upon its outside 60·3 degrees Fahrenheit, and the steam-pressure within it 60 pounds per square inch above the atmosphere, the temperature normal to which is 307·3 degrees Fahrenheit; then its loss of heat per hour will be $(2{\cdot}9330672 \times 450 \times 307{\cdot}3^\circ - 60{\cdot}3^\circ =)$ 326010·42 Fahrenheit units. Or, as the latent heat of steam of this pressure is 897·74 Fahrenheit units, the weight of steam that will be condensed per hour, to water of the temperature 307·3 degrees Fahrenheit, will be $\left(\frac{326010{\cdot}42}{897{\cdot}74} =\right)$ 363·145 pounds; equivalent to a bulk of $\left(\frac{363{\cdot}145}{62{\cdot}388} \times 349{\cdot}13 =\right)$ 2032·2 cubic feet, at the pressure of 60 pounds per square inch above the atmosphere. The proper air temperature to be taken is that of the external atmosphere, not that of the fire-room. In general, let

c be the tabular constant in Fahrenheit units of heat.

a be the area in square feet of the surface of the boiler shell.

t be the temperature of the steam within the boiler.

t' be the temperature of the external atmosphere.

h be the latent heat of the steam within the boiler in Fahrenheit units.

v be the volume of steam of boiler pressure, relatively to the volume of water at the temperature 39 degrees Fahrenheit, from which the steam was generated.

62·388 be the weight in pounds of a cubic foot of water, at the temperature of 39 degrees Fahrenheit; then in general,

$c \times a \times (t - t') =$ the loss of heat per hour in Fahrenheit units.

$\frac{c \times a \times (t - t')}{h}$ = the weight in pounds of steam of the temperature t, condensed per hour, to water of the same temperature.

$\frac{c \times a \times (t - t')}{h} \times \frac{v}{62 \cdot 388}$ = the bulk in cubic feet of steam of the temperature t, condensed per hour, to water of the same temperature.

When the weight of steam of a given pressure evaporated per hour in the boiler, and the temperature of the feed-water, are known, the *proportion* of the heat contained in the steam, which is lost by external radiation from the boiler-shell, can easily be calculated, the *absolute* quantity so lost per hour having been ascertained from the previous data.

The weight of steam evaporated per hour can be obtained directly by previous measurement, in a tank, of the feed-water pumped into the boiler; or it can be obtained, indirectly, from the weight of fuel consumed per hour, and its economic vaporization per unit of weight; in practice, these latter data are most readily available. Now with the average proportions of practice, the grate-surface of a boiler is about one-eighth of the surface of its shell, so that in the case of the example of a boiler with 450 square feet of shell surface, the grate surface would be about 56 square feet. Taking the average rate of combustion of anthracite at 14 pounds per square foot of grate-surface per hour, and its economic vaporization per pound at 8 pounds of water from the temperature of 100 degrees Fahrenheit, and under the pressure of 60 pounds per square inch above the atmosphere, there would be evaporated per hour ($56 \times 14 \times 8 =$) 6272 pounds of steam, to each pound of which the fuel had imparted ($1207 \cdot 68 - 100 \cdot 07 =$) 1107·61 Fahrenheit units of heat, making the quantity of heat imparted to the steam per hour ($6272 \times 1107 \cdot 61 =$) 6946929·92 Fahrenheit units, of which the 326010·42 Fahrenheit units lost per hour, by radiation from the naked shell, are $\left(\frac{326010 \cdot 42 \times 100}{6946929 \cdot 92} =\right)$ 4·69 per centum.

Now as the loss of heat per hour, by radiation, will be the same, so long as the air temperature outside the boiler, and the steam temperature inside the boiler, remain the same, let the weight of steam evaporated in the boiler per hour be what it may, there follows that ***the per centum of the heat lost by radiation, other things equal, will be, inversely, in the ratio of the weight of steam evaporated in equal times.*** Thus, in the case of the previous example, if, instead of the

6272 pounds of steam evaporated per hour, only 3136 pounds had been evaporated, or one-half, then, as the absolute loss by radiation continues the same, its per centum would have been doubled, or become 9·38, instead of the 4·69. On the contrary, had the weight of steam evaporated per hour been one-half more, or 9408 pounds, instead of the 6272 pounds, other things equal, the constant loss by radiation would have amounted to 3·13 per centum of the total heat in the steam above the temperature of the feed-water, instead of the 4·69 per centum, and so on.

The foregoing calculations are, it will be observed, for naked metal—for a boiler without any covering whatever—and show that, under the average conditions of practice, and for a steam-pressure as high as 60 pounds per square inch above the atmosphere, the loss of heat by radiation is less than 5 per centum. This is the margin on which a saving is possible by the application of felt or other covering. Had the boiler been covered with felt 1½ inches thick, the 4·69 per centum loss by radiation, when 6272 pounds of steam were evaporated per hour, would have been reduced, in the ratio of the tabular constants, 2·9330672 and 0·2507097, and become only 0·40 per centum—that is, four-tenths of one per centum of the total heat imparted to the steam. It is only upon this very small quantity that any saving can be effected by the application of additional felt, or of any other non-conductor. Hence, a considerable difference in the non-conducting efficiency of different kinds of covering, having equal thickness, weight or cost, scarcely affects, to a sensible degree, the per centum of heat lost by radiation from boilers; probably not to the extent of the one-thousandth part of the total heat in the steam.

In the following Table, No. 2, will be found the loss of heat by conduction from boilers covered with hair-felt 1½ inches thick, and having 8 square feet of shell-surface to each square foot of grate-surface, in per centum of the total heat imparted to the steam; the temperature of the feed water being taken at 100 degrees Fahrenheit, and that of the external air at 60 degrees Fahrenheit. The determinations have been made for anthracite burned at the rates of 4, 8, 12, 16, 20 and 24 pounds per square foot of grate per hour, and for steam-pressures of 10, 20, 30, 40, 50, 60, 70, 80, 90 and 100 pounds per square inch above the atmosphere. The boiler is supposed to have 25 square feet of water-heating surface to each square foot of grate, and to have an aggregate cross section of tubes for draught, or calorimeter, equal to one-eighth of the grate surface.

TABLE 2.

Steam-pressure in boiler in pounds per square inch above the atmosphere.	Per Centum of the Total Heat imparted to the Steam above the Temperature of the Feed-Water, lost by Conduction.					
	Burning 4 pounds of anthracite per square foot of grate surface per hour. Evaporative efficiency of the pound of anthracite, 9·33 pounds of water from 100° F.	Burning 8 pounds of anthracite per square foot of grate surface per hour. Evaporative efficiency of the pound of anthracite, 9·20 pounds of water from 100° F.	Burning 12 pounds of anthracite per square foot of grate surface per hour. Evaporative efficiency of the pound of anthracite, 8·47 pounds of water from 100° F.	Burning 16 pounds of anthracite per square foot of grate surface per hour. Evaporative efficiency of the pound of anthracite, 7·30 pounds of water from 100° F.	Burning 20 pounds of anthracite per square foot of grate surface per hour. Evaporative efficiency of the pound of anthracite, 6·50 pounds of water from 100° F.	Burning 24 pounds of anthracite per square foot of grate surface per hour. Evaporative efficiency of the pound of anthracite, 6·08 pounds of water from 100° F.
10	0·8672	0·4498	0·3257	0·2834	0·2530	0·2276
20	0·9775	0·4957	0·3589	0·3124	0·2806	0·2559
30	1·0476	0·5312	0·3847	0·3347	0·3007	0·2688
40	1·0826	0·5588	0·4047	0·3524	0·3164	0·2828
50	1·1556	0·5860	0·4243	0·3693	0·3318	0·2965
60	1·1992	0·6081	0·4403	0·3832	0·3442	0·3077
70	1·2384	0·6280	0·4547	0·3957	0·3556	0·3178
80	1·2744	0·6462	0·4679	0·4072	0·3659	0·3270
90	1·3063	0·6624	0·4796	0·4174	0·3750	0·3351
100	1·3401	0·6795	0·4920	0·4282	0·3847	0·3439

In Table No. 2, the per centum of the heat imparted by the fuel to the steam, which is lost by conduction, has been calculated for six rates of combustion increasing by equal quantities, instead of for six weights of steam increasing by equal quantities in equal time, because the one is not a measure of the other, and the rate of combustion is the most convenient reference for engineers. The economic vaporization by the unit weight of fuel decreases in a boiler of the supposed proportions as its rate of combustion is increased; for anthracite, this decrease is shown, for the assumed rates of combustion, by the quantities in the headings of the columns; which quantities are the means from a vast number of experiments.

The per centum in the columns shows how insignificant, under any condition of steam-pressure, is the loss of heat by conduction when the boiler is covered with $1\frac{1}{2}$ inches thick felt; for even with the low rate of combustion of 8 pounds of anthracite per hour per square foot of grate, and the high steam-pressure of 100 pounds per square inch above the atmosphere, the loss is only about two-thirds of one per centum of the fuel, which gradually diminishes to about one-third of one per centum as the rate of combustion increased to 24 pounds of anthracite per square foot of grate per hour.

For medium steam-pressures, say about 30 pounds per square inch above the atmosphere, this loss, with the 8 pounds per hour per square foot of grate of anthracite combustion, is but a little over one-half of one per centum of the fuel, falling to a little over one-fourth of one per centum when the rate of combustion rises to 24 pounds.

If the loss of heat that would take place with the boiler naked instead of being covered with $1\frac{1}{2}$ inches thick felt, is required to be known for the tabular conditions, it is only necessary to multiply the quantities in the columns of Table No. 2, by $\left(\frac{2\cdot933067200}{0\cdot250709717}=\right)$ 11·6990567, in order to obtain that loss in per centum of the heat imparted by the fuel to the steam.

From the experimental data there can also be determined the weight and bulk of air which can be raised one degree Fahrenheit in temperature, by the heat radiated per hour from one square foot of naked boiler-plate $\frac{5}{16}$ inch thick, per degree Fahrenheit difference of temperature between that of the steam on one side of the plate and that of the air on the opposite side.

The weight of a cubic foot of air in latitude 45 degrees, at the sea-level, under the pressure of 29·92 inches of mercury at the temperature of 32 degrees Fahrenheit, and with the temperature of 60 degrees Fahrenheit, is 0·076 pound avoirdupois. This air contains the average proportions of carbonic acid gas and aqueous vapor; and has under constant pressure, the specific heat 0·238. Now, as by the experimental data, the quantity of heat imparted to the air by each square foot of radiating boiler-plate per hour per degree Fahrenheit difference of temperature between that of the steam and that of the air on opposite sides, was 2·9330672 Fahrenheit units, or, in other words, a quantity sufficient to raise the temperature of 2·9330672 pounds of water at 32 degrees Fahrenheit one degree, and as the specific heats of this water and air compare as 1·000 and 0·238 respectively, this

quantity of heat will raise the temperature one degree Fahrenheit of $\left(\frac{2\cdot9330672}{0\cdot238}=\right)$ 12·3238 pounds of air occupying 162·1553 cubic feet. As the specific heat of air does not vary sensibly with its temperature, these quantities will be in the direct ratio of any other number of degrees difference of temperature, and can be employed to determine the quantity of radiating surface with given temperatures of steam and air upon its opposite sides, that is required to heat per hour any desired weight or bulk of air from one given temperature to another.

Suppose, for example, the temperature of the steam on one side of the radiating surface to be 260 degrees Fahrenheit, corresponding to a pressure of 20·8 pounds per square inch above the atmosphere, and the temperature of the air flowing upon the other side to be 60 degrees Fahrenheit, it is desired to know the number of square feet of radiating surface required to heat to the temperature of 70 degrees Fahrenheit, 1500 cubic feet of this air per hour, which are about the volume necessary to be supplied to each man on the berth deck of vessels in order to remain salubrious.

The difference between the temperatures on the opposite sides of the radiating surface being $(260° - 60° =)$ 200 degrees Fahrenheit, each square foot of that surface will heat per hour $(162\cdot1553 \times 200 =)$ 32431·06 cubic feet of air, 1 degree Fahrenheit; or, as the air is to be heated $(70° - 60° =)$ 10 degrees, it will heat per hour that number of degrees $\left(\frac{32431\cdot06}{10}=\right)$, 3243·106 cubic feet. Consequently, $\left(\frac{1500\cdot}{3243\cdot106}=\right)$ 0·4629 is the fraction of a square foot of radiating surface required, under the conditions, to heat per hour 1500 cubic feet of air 10 degrees Fahrenheit; or, in other words, to supply, at the proper temperature, the proper bulk of air per hour for one man.

As the weight of a given bulk of air varies with the temperature, and as the number of degrees through which it is to be heated to the same constant temperature of, say, 70 degrees Fahrenheit, varies with its initial temperature, each case, even with a constant difference between the temperatures on the opposite sides of the radiating surface, evidently forms a distinct problem requiring its own numerical solution; but the process will be the same as shown above, and only requires the substitution of the proper numbers.

ON THE RELATION OF MOISTURE IN AIR TO HEALTH AND COMFORT.[1]

By ROBT. BRIGGS, C. E., Cor. Mem. Am. Inst. of Architects, etc.

[Continued from Vol. lxxv, page 93.]

§ It has been shown how nearly impracticable it is to procure, in winter, with the average temperature of winter, which is 34°, a summer temperature and humidity in our houses. The difficulties of effecting this with 34° for the temperature of the external air are enhanced greatly, as the minimums of cold are reached, and at zero the production of a summer air in a house or place of residence may be claimed to be impossible. If the effect of the changes of out of door temperatures and humidities, which can happen with, at the worst, eight to twelve hours of change, and which, on the average, gives twenty-four to seventy-two hours of interval, is as objectionable; what words can express the effect of the mere passing from a room at summer humid warmth to the open anhydrous air at zero? There are few readers of this paper, who have not tried the experiment of leaving some crowded hall, where the closed doors and windows, and many breaths, had made an approach to the summer condition, and felt the cold air of winter at the bottom of the lungs, as the inactive membrane parted with its unexpected supply of moisture to the anhydrous air. At whatever temperature or moisture condition air be inhaled, it will be exhaled at 90°, and laden with moisture nearly to the point of saturation. Of the heat given out by the lungs, that which proceeds from evaporation is generally largely in excess of what is required to impart heat to the air. Even in the extreme case of breathing air at —40° (or the temperature when mercury freezes, which the writer once observed at Vassalborough, Maine), the heat of evaporation of moisture from the lungs is but a little greater than that for heating the air, being 2·22 units in one case, to 2·18 units in the other, per cubic foot of exhaled air. The skin gives out its heat through insensible perspiration, or through heat imparted to air, in similar, if not the same, proportion.

The establishment of a regime of evaporation from the lungs or skin —of a constancy of secretions—appears to be more essential than the establishment of a uniform temperature, either of the air of respiration or of contact with the person. The stability of the moisture

[1] Paper read before the Am. Institute of Architects, at Boston, Oct. 18th, 1877.

condition, whether in the external air from time to time, or between inside and outside of the room, is what is desirable for health; and this stability, from inside to outside of room, is what we must maintain if we are to live in active, healthful life in our climate. The transfer of heat through the skin or membranes is merely conductive, not involving organic action; while the supply of moisture incident to the maintaining of evaporation, brings into service, vessels, ducts or pores, whose healthful action depends, in great measure, on the regularity and continuity of the said service. This hypothesis will explain at once the healthfulness of the climate of Florida or that of Minnesota in cases of pulmonary disease, and in other parts of the country will account for the prevalence of colds and coughs or the occurrence of rheumatic affections. The diseases of the changeable climate and water-laden winds of our colder Eastern states are bronchial and pulmonary; and (without desiring to intrench on the province of the medical profession, whose known duty at all times it has been to find the cause of disease) it may be safe to attribute them, to a great extent, to the effect of alternate dry and damp air on the evaporating surface of the lungs when the skin has the protection of clothing to keep it warm. The diseases of the warmer mountain-sides of our Middle states, are rheumatic, and may be attributed to the same cause operating, by warm currents of air, on the less unprotected skin.

Beside this view it can be averred that, for the resident or native of any country, there will have established, as a habit, a connection of moisture of air relative to its temperature which is national, so to speak, in which the *variations* of humidity and heat are accepted as a general average. Thus, the American in England is chilled to great discomfort by the low temperature endured by Englishmen, whose systematic evaporation provides for small loss of heat; while the Englishman in America finds a suffocating heat in the dwelling of the American, from the fact that his lungs and skin do not afford the moisture requisite for evaporation and consequent dispersion of heat. A long residence, often two or more years, is needed before the system of either is adapted to the novel condition.

§ Although somewhat late in the course of this argument, and perhaps somewhat elementary as information, it may be well to state the physical laws of the relation of moisture to air. The property of water is to possess in contact with itself, at any and all temperatures, from the boiling point downwards, an atmosphere of vapor,

which vapor has an elastic force, or exerts a pressure bearing some definite relation to the sensible temperature of the water and of itself. The English measures of this elastic force are generally expressed in inches of height of a mercury column, in the same way as shown by an English barometer, which of course applies to any unit of surface, and may be transformed to pressure in pounds per square inch or square foot, by a similar process to what we use for atmospheric pressures. According to Regnault (as quoted in Guyot's tables), some of the elastic forces are as follows:

Degrees Fahrenheit.	−30	−20	−10	0	10	20	32	40	50	60	70	80	90	100	212
Inches of Mercury Column.	0·0092	0·0163	0·0270	0·0434	0·0684	0·1078	0·1811	0·2476	0·3608	0·5179	0·7329	1·0232	1·4097	1·9179	29·922

From which it will be seen that the elastic force falls off rapidly with the temperature. At any given temperature, vapor, possessing the above value of elastic force, exists in the atmosphere as a part of its volume, *whenever there is water present to supply it*, and such an atmosphere is said to be saturated. When there is not sufficient water at hand to supply the vapor due to the temperature; what there is of vapor in the air is slightly superheated, as it accepts the temperature of the air and not that of its tension, but this effect is so small that it may be neglected. The air is then said to be dry; the usual way of estimating such dryness is by naming the percentage of vapor present, to that which would fully saturate the air at a given temperature. Dry air seeks moisture from any source, and the difference of elastic forces, between that of the vapor in the air at any time, and that of saturation of the same air, represents the *avidity* for moisture of such dry air as a species of partial vacuum.

Now the quantity of moisture as vapor accompanying a given quantity of air is neither increased nor diminished in the same air by heating or cooling it (of course in the latter case to the temperature when the air is saturated, below which point the moisture condenses). Hence it does not matter, so far as moisture is concerned, at what degree of heat we introduce the air for warming a room; if only the final temperature of the room be 70° or 80°, then the drying effect of the air of that room upon the persons occupying it, or its furniture, or its materials of construction, is that due to air of 70° or 80°, which air shall contain only the normal moisture of supply. In other

words, our hot air furnaces which supply air at 150° to 200°, do not (except, perhaps, close to the mouths of supply, before the heat is distributed) dry up wood-work or absorb any more moisture from the persons occupying a room, than those which give currents at 80° or 90°, provided the general temperature of the room is the same in both cases. But a yet more important truism can be stated, which is that the drying effect of air of a ventilated room at 70° or 80° which has received no increase of humidity in the hot air of ventilation from out of doors—air that has been warmed artificially from zero let us say—the drying effect of this heated air upon a person occupying it is very nearly the same as if he or she were to maintain the same temperature through active exercise and warm clothing out of doors. The exception expressed by "very nearly," relates to the clad portion of the body—the obstacle presented by the clothing to the free diffusion of aqueous vapor is more effective between the cold air which is but little warmed to demand moisture, and the skin which will give it out if the vacuum demands it, than between the arid air of the room which takes up every particle of moisture as it transpires through the clothing. [As regards loss of moisture from the throat or lungs, however, there is absolutely no difference in breathing the air of the supposed room and that which is then found out of doors, although the one be at 70° to 80° and the other at zero; reiterating the former statement: "In either case the exhaled breath is at 90° as it passes out from the nostrils or lips, and is saturated or nearly saturated with moisture." No one ventures to assert that it is unhealthy, as an act of breathing, for the human race to breathe freely the coldest dry air of winter, because of the supplying of moisture to the anhydrous air. There is an evident fallacy in the assumption that it can be healthy to check instantly that copious secretion which has been supplying moisture to the fresh cold air of zero, by going into a room of summer hygrometric condition, or to demand such an effort of the tissue of the lungs suddenly by leaving such a room for the outer air.] Fortunately, nature is more lenient than the theorists, and we do not get 70° to 80° with 70 per cent. of saturation in the most unventilated or uncomfortably heated houses, and with all efforts to the contrary, even 40 per cent. is of unusual attainment when the external air has a temperature of zero.

It must be admitted, however, that some small degree of hydration is a necessity for comfort, and with comfort for a demand, some reason

may be found to establish the healthfulness of the small supply. It is certain from all experience that from 5 to 10 per cent. of moisture can be added to air after it is heated, certainly with much relief, especially to the eyes, with apparently little harm, although such addition may make the occupant of a heated room a little delicate as to out-door exposure. Moisture may to some small extent be abstracted by the means of heating, especially when the heating is by stoves or hot air furnaces; at all events the presence of a sheet or surface of water over which the heated air is allowed to pass, is now a recognized means of supplying a small quantity of aqueous vapor to air of ventilation. But the quantity supplied in this way is very small in comparison with what is needed for complete "hydration," or even for what can be denominated "hydration" at all, in the sense of a summer condition. From an estimate based on several winters' experience, a vaporization of water which supplied a half grain of vapor per cubic foot of air introduced, when an increment of four to six grains for the same volume of air would be requisite to get the summer condition of humidity corresponding to the internal temperature, has proved sufficient to give a sensibly pleasant air, while the absence of this supply was at once perceptible in the house. A low pressure hot water apparatus, whose temperature never reached the boiling point, and rarely exceeded 180°, giving heat to a large volume of fresh air, which, at the mouths of supply to the rooms, was not much above 90° at any time, was the source of heat.

§ It is very difficult to find any hypothesis which will account for this requirement of a small supply of vapor with heated air, when we admit, or can demonstrate, that the sufficient quantity to the senses is so far below what is needed for hydration, and so independent from the moisture condition of the air; for nearly the same small quantity of vaporization seems desirable in air heated from any temperature. The explanation of the offensiveness of heated air currents has been sought with much diligence, and, at times, causes have been assigned with much positiveness. One of the earliest of these explanations (but one which yet finds supporters) was found in the substitution of transferred or convected heat by currents of air for the radiant heat of fire. Open fires were to be restored as the means of securing pleasant air. The healthfulness and comfort of our ancestors were to come back to their degenerate children. Gathered around a blazing fire, roasted on one side and frozen on the

other; restricted to one fire in the house, as all the others *would* smoke; the chamber-heating apparatus reduced to the warming-pan; victims of rheumatism, sciatica, tic-douloureux and ague—the diseases of fifty years ago—the good old times were to come back. Alas! there were obstinate innovators, and the world would not be convinced of the advantages of radiant heat as the sole means of warming.

This point being established, at a later time, surfaces at high temperatures for imparting heat to the air of a room, either by ventilating currents or direct heating, including all fire-heated surfaces, together with steam-heated ones, above the boiling point, or 212°, were utterly condemned. Somebody discovered burnt atoms of dust in heated air, and its destructive, pernicious effect on the health was at once apparent! But the comfort of the community some way overruled the theory, and hot-air furnaces, with admitted deficiencies in quality of air, met greater favor than ever. It is allowed, generally, that the expensive steam-heating apparatus is at once the more pleasant, controllable and durable; and that the yet more expensive hot-water apparatus, with its great volumes of low temperature currents of air, is the best of all means of heating. The cost in fuel by these several apparatuses becomes nearly the same, for equal effects, in warming of houses.

The next demonstration was the chemical one. An occult effect is most conclusively, if not convincingly, explained by an occult cause. Ozone is a favorable object to carry a theory, and it really is possible, if we knew anything definite and certain about the origin or the effect of ozone; some relation of this phenomenon of the requiring the evaporation of a small quantity of water, when heating air, might be traced. But no blinder pathway in science was ever opened than the ozone one. After this came Deville and Troost's discovery of the permeability of some metals, when heated at, or nearly at, red heat, to some of the gases. In the language of one of the most prominent writers on ventilation, this "explains the very injurious and even poisonous effects produced by the use of stoves in the rooms of a dwelling!"

The last resort of the unreasoning theorizer in physics is always to electricity, and efforts have not been wanting to show that either the presence or the absence of electricity, in some form or condition, ought to have something to do with the discomfort arising from heated air.

The only answer to this hypothesis is that heated air is equally oppressive in entire absence of water supply, whether highly electrical or otherwise; our vicissitudes of climate and of humidity enabling a test of electric condition in extreme cases. There are times in any winter, in the Northern states, when it is possible to gather enough electricity, by walking over a carpet, to make the spark from the finger which will light a gas-light. The quantity of water demanded at such times by a heating apparatus, is no greater than at other times. There is not the least positive proof of relation of electricity to the healthfulness of air. Altogether, the whole resolves itself to the reiteration of the bare fact, that it is comfortable to evaporate a small quantity of water in heated rooms, and that it can be done without marked injury to the occupants or to visitors. The quantity itself seems to be almost constant for all temperatures or hygromations of the air, and to be a slight addition only to the moisture in the normal air out of doors at any time.

§ The effect of draughts on currents of air upon any person exposed to them is materially modified by the hygrometric condition. In still air in winter the comfortable temperature of a room in general hygrometric condition has been stated at 70°, but a current of air upon the person at this temperature is uncomfortably cold from the rapid abstraction of heat, while in summer the same temperature, accompanied by the summer dew point, will be warm enough to demand light clothing, and a current of the same velocity will not be objectionable; in other words, draughts which cannot be tolerated in our houses in winter, become pleasant breezes in summer. Not only the speed or rate of velocity of the current of air is to be taken into account, but its avidity to take up moisture from the skin as indicated by its dew point. So long as the hygrometric condition of the air is such that will absorb moisture below 98°, a blast of it at some rate of current will be a cool one.

One fans himself in our climate, when the thermometer stands at 100°, with a sensation of relief. This feeling of cold, from air of high temperature, when in motion, proceeds from the rapid removal of the stratum of warm and nearly saturated air in contact with the person, and its replacement by fresh air, which is not only cooler, but which has not yet become saturated or charged with moisture by contact with a moist surface like that of the skin. In no one of the changes in the three forms of matter—solid, liquid and gaseous—is there so

much heat taken up as in the change from a liquid to a gaseous (or vaporous) form, and in no other body or substance is so much heat absorbed or become latent as in the formation of steam from water, or in other words, in the process of evaporation; and the quantity of heat taken up by the moisture which a dry air abstracts from the skin is so great, that the mere differences of temperature of the air, from that of the skin, may almost be neglected in the statement; and it is very nearly correct to assert that the cool sensation from a breeze in summer, proceeds entirely from the evaporation of moisture thereby induced.

Upon this basis it may be noticed that a current of saturated air at 100° would neither remove heat by its contact nor by induced evaporation, and consequently would be incapable of producing a cooling effect, while as the temperature or the dew point should fall, the current would become a pleasant one. With a high temperature and dry air, the cooling effect of a current of air (even at 100°) may be very pleasant in the sensation, but will be attended with sun-burning (even without exposure to the sun), and blisters will be produced by the excessive deprivation of moisture from the cuticle or surface of the skin. With 80° of temperature and a high dew point, a strong breeze is not unpleasant, nor likely to be injurious after the person shall have acquired some *accustomed* habit of body to endure it; but at 70° and a low dew point, which is the only possible condition of heated air in mid-winter, the annoyance of a current of even five feet per second and its unhealthiness are positive facts.

§ There remain to be considered two more relations of moisture in air, to health and comfort. First, the effect of evaporation of water by the air itself in summer, in reducing the temperature to one of comfort; and secondly, the effect on the moisture condition of the air of summer, when it is attempted to cool air by artificial means.

The cooling of air, by spontaneous evaporation from extended surfaces, is of frequent practice in hot countries by the wealthy inhabitants near the banks of rivers where the water supply is abundant. The condition of the air which makes it practicable is one of great heat, and of a relatively low dew point; and the summers of Egypt and of parts of India, especially of Bengal, give opportunity to employ this method of cooling air. If it is accepted that the temperature of the air in the shade, in the localities referred to, will sometimes run from 85° to 105° for many consecutive hours, accom-

panied with, say, 50 per cent. of moisture for the 85° of temperature, or, say, 30 per cent. for the 105°, then the evaporation of moisture from wet surface can be relied upon to produce a comparatively comfortable atmosphere. Air at 85°, with 50 per cent. of moisture, has quite exactly the same quantity of moisture, per given volume of air, as that at 70° and 70 per cent. of moisture. So that if it could be cooled *without* adding moisture at all, it would then reach the point of comfort for the clothed inhabitant of the temperate zone. If the dew point of 85° is brought up to 80 per cent. or above, the air becomes intolerably sultry, and at 90 per cent., quite suffocating; so that the greatest addition of moisture practicable to the supposed air of 85° and 50 per cent. dew point, may be taken as 10 per cent., or $1\frac{1}{4}$ grains to the cubic foot. The resulting figures which the latent heat demanded for the evaporation of these $1\frac{1}{4}$ grains of moisture into the air supposed, is $74\frac{1}{2}$°, and 82 per cent. of humidity. How far this condition of the air may be more comfortable than the original one of 85° and 50 per cent. of humidity, is questionable; but it is apparent that the limit of possible cooling of air of 85°, by evaporation of moisture, is found when its humidity is not to exceed 50 per cent. of saturation. A similar computation applied to air of 105° (in which air there is a little more moisture than in that supposed at 85°) gives, for the addition of $1\frac{1}{4}$ grains of moisture to the cubic foot, air of $94\frac{1}{2}$° temperature and 48 per cent. of humidity—an atmosphere which *may* be, in some degree, more comfortable to a person at rest than the normal one. It is evident, that for efficiency in cooling air of 105° by evaporation from moistened surfaces, the humidity of the air to be cooled should be less than 30 per cent. As to ultimate healthfulness of the moistened air, it *seems* to be unquestionable that the supply of moisture ought to promote disease.

We have, however, in each year in our country, a few days or parts of days (perhaps, in the Southern Middle states, ten to twenty days in different years), when the range of thermometer and the dew point make it feasible to adopt this means of reducing the apparent heat of the air. The attempt has been frequently made, with provoking failure to the projectors. Its success depends upon not only the exact condition of relative humidity and temperature, but also on the proportion of surface of evaporation to the quantity of air to be supplied. The Indian ratio is one or two persons to six to eight square yards of wet surface. But the most provoking cause of

failure has been, that while there are ten to twenty hot dry days in any year, there are also twenty to thirty hot damp ones, and the application of the *cooling* apparel to the hot air on these days, has produced such an effect of sultriness that the whole has met with instant condemnation.

The last relation of moisture to air to be considered at this time is that which proceeds from the effort to cool air artificially. The fallacies of the attempts to effect this purpose can be made very apparent. Even the smallest decrement of heat is obtained only at great cost. The *quantity* of cooling of air in summer is, to be sure, only about one-fourth that of heating in winter. Taking the ideal temperature of 70°, there may be 15° to come off in summer as generally as 60° to be added in winter, and supposing iced water to be the cooling medium, and steam of low pressure to be the heating one, the relation of difference of temperature of the air to be cooled or heated to that of the iced water or steam, is such, that about the same extent of surface would be required in either case to transfer the heat. But a pound of coal produces, in ordinary steam boilers, quite 9000 units of heat on the average, while a pound of ice (in cooling to 60°, let us say) will produce only 170°, so that about 54 pounds of ice would be demanded to effect the transfer of an equal quantity of heat, to what would be effected by 1 pound of coal; or, accepting the one-fourth cooling effect, then 13½ pounds of ice would be demanded for the cooling of air in summer against each pound of coal required for warming in winter. Unfortunately for the proposition for cooling *air* in summer, even this statement is too favorable, for the requirement will be found that the air must not only be cooled, but must be divested of a portion of its moisture, unless the cooled air is deemed satisfactory in the form of a cloud of vapor. Air at 85° and 70 per cent. of humidity must be taken to be cooled to 70° and 70 per cent. of humidity, and one and one-fourth times as much cold will be demanded to condense the vapor 2·3 grains per cubic foot, as that which is requisite to cool the air the 15° supposed. This leaves the ratio of ice needed to obtain a spring condition for the air on a hot day in summer, to be that of 30 to 1 of coal usually demanded to heat air on a cold day in winter, or assuming that the air on such a day is so dry that no moisture should be removed, about 15 to 1. Our ideas of the necessities of civilized wants, as compared with civilized luxuries,

scarcely yet reach high enough to warrant the expenditure of money to cool air under the circumstances stated.

In view of the great cost of cooling air by ice, it has been proposed to cool it by mechanical means on a large scale. Air, if compressed, becomes sensibly hotter. The compression can be carried to the extent that the heat will ignite tinder, as the cigar lighters of twenty or thirty years since bear witness. And it has been proposed to use large air pumps which shall compress the air until its temperature is elevated sufficiently for it to give off heat to surfaces cooled by currents of water, at such temperature as water is to be had from streams or aqueducts in summer. This compressed air, when deprived of a portion of its heat, is then allowed to expand, and the result is a cooler air. This process really has considerable merit, and it is probable that the cost of producing cold in this way, compares favorably with the use of ice; in fact it has been shown that ice itself may be manufactured with profit by this process in some localities, where transportation enhances the price of ice largely. But it is preposterously expensive for apparatus and cost of working as a means of cooling air in the great quantities demanded for ventilation, and the humidity of the cooled air will still be objectionable. The comparatively high temperature of the surface for cooling the air will fail to be very efficient in condensing the vapor thoroughly. In both the methods of cooling air, whether by ice or by water (of which great quantities would be needed), the cooling surface must be copper, brass or tin, as the rusting of iron, when exposed to condensing vapor, is extremely rapid.

The most probable result of cooled air would be a thunder-cloud in miniature. The atmosphere on one of our hottest and most sultry days of summer is on the verge of a tempest. Cooling of air of 85° to 90°, to the extent of 20° or 30°, produces a dense mist of supersaturated cooled air. The equilibrium of the atmosphere on a still, clear summer day, when every growing thing on the surface of the ground is supplying moisture, and the radiation of the ground itself is supplying heat to increase the relative levity of the strata of air next the ground—the equilibrium of such an atmosphere is very unstable. Let an upward flow be established anywhere, and the air will rush in all directions along the surface to supply the partial vacuum. The ascending column, as it reaches the region of lower barometrical pressure, will expand, become sensibly cooler, and in a short five to

eight miles of height, the region of frost and ice will be reached, and hail-stones will be returned from the condensation of the transparent vapor which had existed in the air when it left the surface of the ground. The writer once saw in a little ball-room, on a Christmas Eve, a miniature snow-storm deposit a little bank of snow, from the opening of windows to air the room, when the dancers had retired; the night being a clear moonlight one, with the thermometer a little above zero.

[The difficulty of absence of moisture in air that is heated in winter is a matter to be disposed of with some happiness, by asserting that moisture is not wanted, and in summer the objection of presence of moisture in cooled air can be only overcome by not cooling the air. It does not seem that the successful cooling of our summer air, so as to produce a comfortable or healthful condition at spring temperatures, has any probability of accomplishment.]

Quoting as an appropriate final remark the words with which I concluded another paper having an especial application to a system of ventilation: "I will not follow further the proposition to change the seasons into a perpetual springtime—practical ventilation is the supply in dwellings, of an abundance of fresh air at the several seasons, warmed to the temperature of comfort in winter, and supplied in quantity to the volume of comfort (as near as possible of the quality and condition of out of doors in the shade) in summer. The truth is, all our heating and ventilating appliances are the compromise of condition—a truth extending beyond all mechanical operations to the phenomena of nature itself."

Note referring to Argument in this Paper, as related to English Experience.—The following quotation from a recent English writer, will convey some idea of the effect of the supersaturated atmosphere of a London fog: "There can have been but few people in London last November (1873), who did not, during the heavy fogs, experience some difficulty in breathing—in getting a sufficient supply of oxygen for the lungs, to carry on the vital processes in the usual manner. On one of the last days of its duration, many people one met in the streets seemed to find breathing painful; they were apparently now and then gasping for breath, and the thought occurred that it was by no means impossible, by a continuance of such weather, for a whole cityful of people to be suffocated. The mortality amongst the sick was very great, and the state of the air caused the death of many prize fed beasts sent to the cattle show at the agricultural hall, at Islington. It would be wrong to suppose that the air was impoverished of oxygen to such extent as to cause asphyxia, but a serious amount of inflammation, and, perhaps, a partial obstruction of the air passages of the lungs, was caused by the inhalation of soot, tarry matter and chilly particles of water."—"*Air and its relations to Life*," Dr. Walter Noel Hartley, London, 1876. 2d edition.

THE HAYFORD PROCESS AND APPARATUS FOR PRESERVING TIMBER.

By EDWARD R. ANDREWS, of Boston.[1]

[Continued from Vol. lxxv, page 118.]

VALUE OF PROCESS.

Now let us retrace our steps, and see whether, practically as well as theoretically, the advantages claimed for the Hayford patents have been realized.

I have shown you that to preserve wood from decay, it must be placed in the following conditions:

1. It must be rendered non-fermentable by the coagulation of the albumen of the sap.

2. *Dryness* must be secured by the abstraction of the sap and moisture contained in it, as well as any sugar or acids, which would have a tendency to ferment.

3. *Dryness* and a pure woody fibre being secured, these conditions must be maintained by protecting the wood in some way from air and water afterwards.

In reply, I claim: First, that inasmuch as albumen coagulates at 140°, and that all the sap containing albumen is to be found in the sap-wood, and that it has been steamed to 240° or 270° Fahr., the albumen has thus been rendered non-fermentable. Moreover, creosote oil contains the most powerful coagulator of albumen known to science—carbolic acid; hence, when injected into the pores of wood, it doubly secures it from fermentation.

Secondly. By the action of the steam heat, and the subsequent use of the vacuum pump, the sap and water held in the wood have been vaporized and withdrawn from the pores of the wood, leaving a pure woody fibre. Nothing liable to ferment remains in the wood.

(This system of drying lumber can be made very valuable for carpenters. In twenty-four hours green lumber can be seasoned more completely than in an ordinary dry-house in six weeks. For this purpose the drying process should be continued for some time after the vacuum has been reached, the heat being kept up by the radiating coil of pipe.)

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[1] Paper read before the Franklin Institute, January 16th, 1878.

Thirdly. Freedom from liability to fermentation and dryness being secured by the earlier processes, the wood is made water-proof and air-tight by injecting the pores with creosote oil.

Creosote oils are also called dead oils, or the heavy oils of tar. They contain from 5 per cent. to 15 per cent. of carbolic acid, and several other highly antiseptic and preservative constituents, besides paraffine, naphthaline, etc., which all play their parts in the preservative processes. Heavy oils are produced in the distillation of crude coal tar, as it comes from the gas houses. They come off after the light and volatile aniline oils, say at a temperature of 300° to 600°. The residuum is pitch.

Creosote oil, forced into the pores of wood at a high temperature, being far more penetrating than any other oil, works its way through the pores until it covers every fibre with a protecting film. It resinifies in the outer pores, and, impacting there, keeps the main body of oil within, and, being insoluble in water, it forms a water-proof and air-tight covering to the wood, and maintains absolute *dryness.* No matter where the wood may be exposed, it is protected from absorbing any fermentable substance. Hence, decay is rendered almost impossible.

The preservative qualities of the heavy oils of tar are not due, solely or chiefly, to one or more of its component parts, although several are esteemed highly as preservative substances; but their efficacy is due, chiefly, to the thick, greenish oil itself, which is *insoluble.* It is this quality, *insolubility*, which gives to the heavy oils of tar their superiority, as preservatives, over chloride of zinc, sulphate of copper, or corrosive sublimate. These latter only coagulate the albumen, they offer no protection whatever to the wood itself; the woody fibres are as much exposed as ever to absorb destructive agents. But when wood has been injected with creosote oil, which works insidiously through its fibres, not only is the albumen coagulated, but the whole structure is so absolutely preserved and protected, that its indestructibility is assured, except from actual wear. It is benefited on this score, also, as it becomes harder by time. Creosoted wood is the only wood which seems to improve with age. The oil seems to metalize the fibre like iron. Soft wood becomes hard, like oak. Sap wood becomes as hard and durable as the heart-wood.

In the early part of my remarks I stated that the Hayford patents, for preserving wood, covered a system which is adapted to the wants

of this country. This is mainly, as you have observed, because it is able to cope with green lumber. It can receive it from the saw-mill, and in 24 hours thoroughly season and preserve it. In fact, to do good work it is essential to have green wood. It is precisely in this condition that wood will readily absorb creosote oil, when the moisture has been withdrawn. In a living tree, the fibres and pores of wood are not hard and flinty, like those of kiln-dried or air-seasoned lumber, but are soft and porous. The cells act as so many millions of pumps, to transmit the sap from the roots to the leaves and return it again to form the annual layer of wood growth. When the sap has been withdrawn from wood in this condition, as has been described, without hardening the fibres, the cells and fibres are just as ready to receive or transmit creosote oil as sap itself.

Creosoted Wood will not Decay.

I have assumed that you are all familiar with the fact that wood thoroughly creosoted will not decay. This is a fact, proved by the accumulated evidence of 40 years in England. Creosoted wood has never been known to decay. Engineers in this country need not wait a generation to learn that this is so. It was accepted as proved in England 30 years ago, and in engineering works the strongest testimonials of the value of creosote oil, as a preservative against decay, are recorded by all the great constructive engineers in Europe.

There is scarcely a railway in England which does not use creosoted ties, bridge timbers and platforms, and the same roads use them to-day which began their use in 1840. The Belgian system of railways, which is under government management, uses creosoted ties solely, and the same is true of all the railways of Northern Europe.

Some engineers here have told me that ties wear out before they rot. That may be true in some cases; but I ask, if creosoted ties do not wear out in 20 years on the great roads in England, why should they wear out here? It is a remarkable fact that it is difficult to find any old ties in England for specimens of creosoted work. These specimens from the Great Northern Railway of England, which have been in wear from 10 to 14 years, were actually taken out of the road-bed to be sent to me. No piles of old ties lying by the side of the tracks, only fit for fuel, are to be seen in Europe as in this country.

My belief is, ties begin to decay before they begin to wear out. As a rule, ties are half buried in the ground in a green state, full of

sap in a fermenting condition. Wet rot sets in at once, favored by the exposure to alternate dryness and moisture, particularly under the rail, where the surface begins to decay at once, hastened by the rust from the rail; at the same time the spike driven into the moist wood begins to corrode; water works down by the side of the spike, the spike loosens and plays, and then comes the trip-hammer action of the rail every time a train passes over it. It is no wonder the tie cuts and is thrown out, often within the first year.

But with a creosoted tie the spike will not corrode and will not work loose; the surface of the tie under the rail will not decay or wear, because not affected by alternate dryness and moisture; there will be no play of the rail upon the tie, and consequently no friction and no cutting. No, there is every reason for believing that creosoted ties will last here 20 years as well as in England, and their general use would be equal to a saving of 3 per cent., per annum, on the cost of the railways of this country.

I have referred principally to the uses of creosoted wood on railways, because they are the great consumers of lumber, but it should commend itself equally to architects, builders and carpenters.

Creosote as a Protection against the Teredo, etc.

I have referred thus far to creosoting as a protection against decay only, but it is equally a specific against destruction of wood by marine worms. This quality of dead oils is almost as important as their efficacy against decay. Bear in mind that from Maine to Texas there is scarcely a point on our coast, where our piers and wharves are not rapidly destroyed by the Teredo Navalis, or the Lymnoria Terebrans.

On the table before me are specimens of wood destroyed by these ravagers at different points, in a few months or years, at Boston, Provincetown, New York, and the Gulf of Mexico.

So far as I am aware, the teredo is not found north of Cape Cod, but the lymnoria is scarcely less destructive.

In many places in the Gulf, the teredo will destroy large piles in a single year. They are found sometimes two feet long.

The teredo infests the coasts of Great Britain, Holland, Belgium and France, and is quite as destructive there as here; were it not for the use of creosoted piling, the piers of their harbors would require to be rebuilt every three or four years. There is not an

instance on record where a pile, impregnated with creosote, to the extent of 10 or 12 pounds to the cubic foot, has been approached by the teredo or the lymnoria. Piers built in 1850 are perfectly sound to-day.

Places where Creosoted Wood has been used as a Protection against the Teredo, in Great Britain.	Dates. When exposed.	Dates. When last examined.	Duration.
Port of Sunderland, . . .	1839	1859	20 years.
" Teignmouth, . . .	1842	1849	7 "
" Lowestoft, . . .	1846	1859	13 "
" Leith, . . .	1848 1854	1862	14 " 8 "
" Southampton, . . .	1848	1852	4 "
" Brighton, . . .	1848	1851	3 "
" Manchester, . . .	1850	1861	11 "
" Portland, . . .	1853	1861	8 "
" Holyhead, . . .	1854	1861	7 "

The importance of protecting these harbor works has been considered so serious a matter, that most careful experiments have been tried, extending through a series of years, under commissioners appointed by the different governments, whose official reports are accessible to all. Every other suggested remedy was tried, and failed in every instance. The terrible mollusk or crustacean seemed to fatten upon every poison, and would manage to work its way between copper- or iron-headed nails or copper plates, but he turned his back invariably upon creosote.[1] All the official reports agree upon this point, that creosote, and that alone, thoroughly injected into wood, will protect it completely.

There is, however, one other remedy, and that is sewerage. It is fortunate that sewerage serves one good purpose. These enemies require clear, salt water, free from any brackishness. It carefully avoids a pier in New York, where a sewer empties, but it luxuriates in the next, which is free from that nuisance.

[1] See papers by E. H. Von Baumhauer, on "The Teredo, and the means of preserving wood from its ravages;" Archives of Holland, Vol. I, 1864. Auguste Forrestier, Engineer of Roads and Bridges; Annales Françaises, 1864. M. Crepin, Engineer of Roads and Bridges of Belgium; Report of experiments at Liege, from 1857 to 1867.

The importance of creosoting ship timber should not be overlooked. I have specimens of birch before me taken from the side of a vessel, which had been six months at Key West, completely riddled by the teredo. How often may it be that vessels, lost at sea and never heard from, have sprung a leak through some teredo eaten timbers. Remember, too, that dry rot would be prevented also, and, perhaps, all necessity for copper bottoms. It would seem that creosote is as useful at sea as on land. Its use is everywhere a true economy.

Our own Government has the honor of being the first to creosote ship timbers. In 1872 creosoting works were erected at the navy-yard in Charlestown, under the superintendence of Mr. Hayford, who took charge of the treatment of the timbers for the "Vandalia," the vessel which is now the home of Gen. Grant, in the Mediterranean.

The ribs of the "Vandalia" are of live oak, but all the rest of the planking and decks, inside and out, were creosoted by Mr. Hayford. This vessel was completed in 1873, and fitted for sea in 1875. Thus far no report has been made of her condition to the Department.

It is well to select, for creosoting, woods which are porous and will absorb oil readily. Cheap woods, which, unpreserved, rot quickly, can thus be made more solid and more enduring than the most expensive timber. I think the cotton wood of the Southwest can be made as useful as oak for ties. White pine absorbs creosote like a sponge, and the yellow pine of the South takes it readily also. In England, fir from the Baltic is used altogether for ties, and I do not see why the despised fir from our forests may not be used for the same purpose here. Hemlock is good also; it holds a spike well. Spruce is a firm, compact wood, and absorbs oil with more difficulty, neither does it require so much to preserve it. Its sap-wood, where decay commences, is always saturated, and the heart, if treated green, shows more or less oil all through the annular rings. Oak has a coarse fibre, and is easily treated.

The limits of a single evening are insufficient, Mr. President and gentlemen, to do justice to so important an industry as this. I thank you for your kind attention, and need not say that I shall be glad, as far as I can, to answer any questions which may lead to a clear and full understanding of a subject in which so many of you, I am sure, must feel a deep interest.

The speaker presented, in support of his views and statements, a large number of letters from engineers in this and other countries, referring to some important works where creosoted timber had been exposed for many years, with the most satisfactory results: among which are the Yorkshire and Lancashire Railway, England, Southern Railroad, France, the Leith Pier, Edinburgh, Scotland.

Among the letters is the following, referring to the

WEARING OF RAILROAD TIES.

"*Boston, Feb. 6th*, 1878.

"EDWARD R. ANDREWS, ESQ ,

"*Dear Sir:*—In answer to your enquiry, I will repeat what I said at a recent meeting of the Boston Society of Civil Engineers, on the subject of treated and untreated railroad ties. I have been of the opinion for some ten or twelve years, that the frequent remark that 'railroad ties will wear out (*i. e.*, cut through) before they will rot out,' is an incomplete and misleading statement, as it is usually made. It supposes that treated (creosoted, kyanized, Burnettized, etc.) railroad ties will wear and cut the same as untreated ones; whereas the *fact* is, as shown by the records of foreign railroads, beyond dispute, that treated ties *wear* longer, do not *cut through* so quickly, and hold the spike longer than untreated ties. I have my own explanation of this fact, but whether the same is correct or not, is really a matter of no especial importance. What we are after are the facts. Still, I will give the explanation that I have arrived at for my own satisfaction, submitting the same to criticism. It is that, after all, what we call 'cutting through,' 'wearing out,' 'refusing to hold the spike,' etc., in railroad ties, is nothing more or less than rotting, with this single distinction, that it is a local rotting, a decay in certain spots and places only, and not that of the whole body of the tie; and that, therefore, a treated tie, which resists decay better, any and everywhere, within it and on its surface, will wear longer, cut less, and hold the spike longer.

"The first time I had occasion to reason in this manner, was in observing the dropping down into the ties of the cast-iron chairs of a piece of 'English' double-headed rail track on the Boston and Albany R. R. The chairs were frequently an inch and an inch and a half imbedded in the tie, and the cup so formed was filled with water after every slight rain or heavy dew, and it seemed to me plain that this concentrated wetting and drying in that spot could not fail to rot the tie faster right under the chair than elsewhere; and adding that to the pounding action of the traffic over the road in the same spot, it made clear to me why the tie wore out before it rotted out, and at the same time satisfying me that a 'properly treated tie' would behave better under the same circumstances.

"Respectfully yours,

"CLEMENS HERSCHELL,

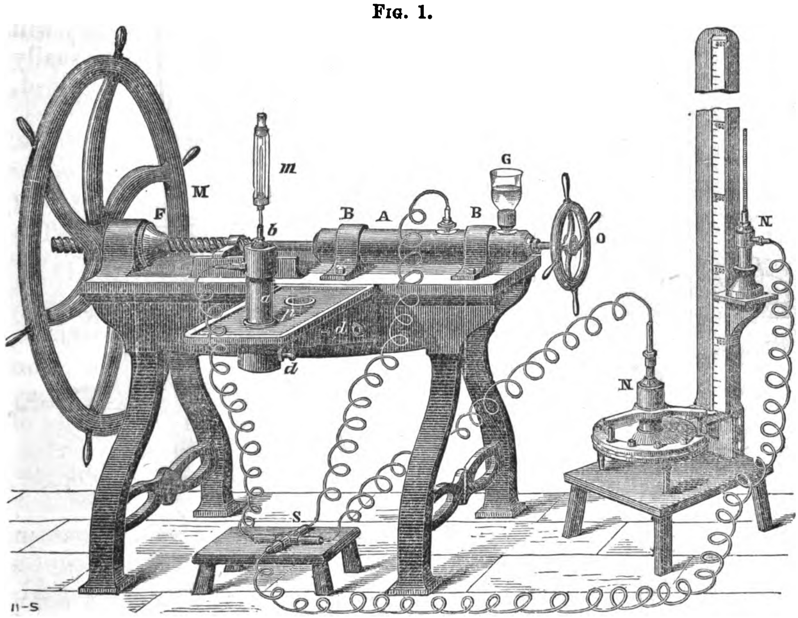
"*Civil and Hydraulic Engineer.*"

M. CAILLETET'S APPARATUS FOR LIQUEFYING GASES.

In the last number of the JOURNAL were given illustrations of the apparatus employed by M. Pictet for liquefying gases, and a brief description of that employed by M. Cailletet for the same purpose, and we are now able to give illustrations of the latter.

In Fig. 1, *A* is a hollow steel cylinder, bolted down by means of the straps, *B*, *B*, to the bed of the framing which supports the apparatus. Entering this cylinder is a steel plunger, having cut on its outer end a square-threaded screw working in the nut, which

FIG. 1.



forms the hub of the large hand-wheel, *M*. The nut is supported by, and revolves in, the strong journal-box, *F*, in such a manner, that the plunger will be advanced and retreated according to the direction the large hand-wheel, *M*, is rotated. The cylinder, *A*, being filled with water, a very high pressure may be produced in any vessel to which it may be connected, upon turning the large hand-wheel. A leather cupped packing prevents the escape of water around the plunger.

The cylinder, *A*, is filled with water through a passage at the bottom of the cup, *G*, which passage is controlled by a conical pointed screw-plug, operated by the small hand-wheel, *O*, as shown. This opening is also employed to relieve the pressure brought to bear on the gases experimented on, allowing their sudden expansion. At-

Fig. 2.

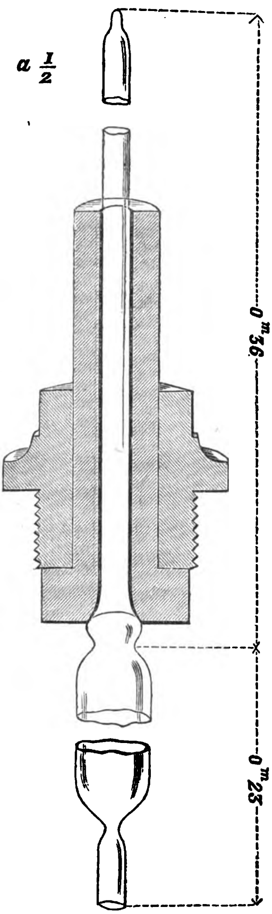
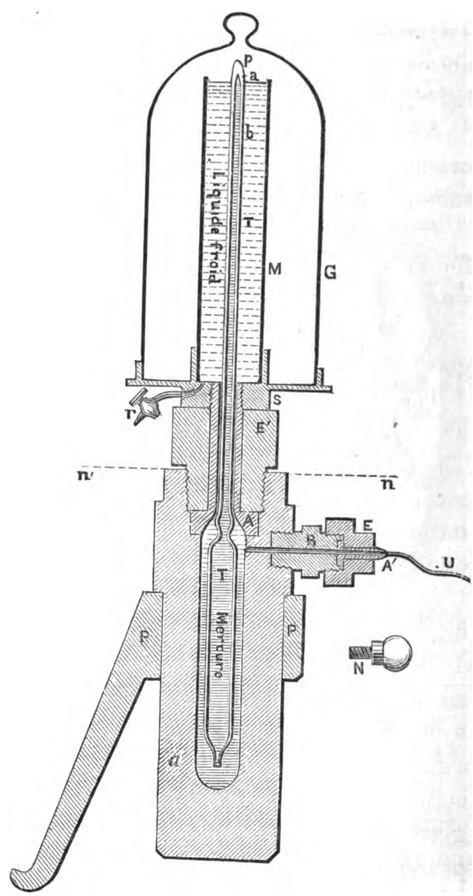


Fig. 3.



tached to, and supported by, the tablet, *p*, is the hollow cylinder, *a*, capable of sustaining a pressure of 900 to 1000 atmospheres, and is connected to the compression cylinder, *A*, by a small metallic tube. The lower and enlarged end of the glass tube, containing the gas to be experimented on, is inserted into the reservoir, *a*, and held in

position by the hollow plug at *b*, as shown in Fig. 2, which is half size.

Fig. 3 represents all this portion of the apparatus in section, supported on a simple tripod, *P*, for use in lecture experiments, in connection with any powerful force pump. Surrounding, and concentric with, the upper end of the tube, *T*, *T*, is placed the cylinder, *m*, which is filled with liquid nitrous oxide, or other freezing mixture. The exterior envelope, *G* (not shown in Fig. 1), contains material to absorb the moisture, which would otherwise collect on the glass cylinder, *m*, and obstruct observation.

N and *N'* are gauges for determining the pressure employed, and are connected to the other portions of the apparatus by small metallic tubes, through the branch piece, *S*.

E is a hollow nut for connecting the pipe, *U*, and *N* is a plug for closing the orifice in *R*, when the reservoir, *a*, is being filled with mercury.

e is a cock for drawing off the liquid freezing mixture from the glass envelope, *m*.

The tube, *T*, *T*, while open at both ends, is filled with the gas to be experimented on, and the upper end, *p*, is hermetically sealed. The other end being closed with the finger, it is introduced into the receiver, *a*, in an upright position, and the mercury, with which the latter had previously been nearly filled, enters the lower end. The other parts of the apparatus are then placed in position, as shown.

Upon turning the large hand-wheel, *M*, Fig. 1, in the proper direction, the water from the cylinder, *A*, is driven into the receiver, *a*, through the tube, *U*, Fig. 3, and pressing upon the surface of the mercury, forces it into the tube, *T*, *T*, reducing the space occupied by the gas in its upper end. After this operation has proceeded for a few minutes, a mist of compressed gas is produced, which finally collects, in a small liquid mass, at *b*. The large end of the glass tube, *T*, *T*, is subjected to the same external and internal pressures, and, therefore, is not liable to break. The upper portion, having a very small bore and thick walls, is sufficiently strong to support the pressure, and should it be ruptured, no serious consequences could result.

The apparatus is easily managed, and with it, and the aid of the oxy-hydrogen light, all the phenomena of the liquefaction of gases can be projected on the screen.

DENSITY OF LIQUID OXYGEN.[1]

By M. Raoul Pictet.

"You arrive at the expression of the density of liquid oxygen as being represented by $\frac{16}{16} = 1 = \delta$ in the solid state, and probably the liquid one also, neglecting the variation due to expansion.

"I have the great satisfaction of being able to announce to you the complete experimental demonstration of the theoretical views enunciated by you now some time ago at Geneva. This demonstration has been arrived at as follows:—

"I know directly and very exactly—

"I. The exact volume of the interior of the wrought iron shell and the volume of potassic chlorate decomposed into oxygen and potassic chloride.

"II. The temperature of the shell at the moment of complete decomposition.

"III. The volume of the tube in which the condensation of oxygen is brought about.

"IV. The pressure before and after condensation.

"V. The pressures indicated by the manometer after two or three successive jets, till the moment the point of saturation is reached, and after which the gas issues in a gaseous form.

"These various data, combined with the gaseous density pressure and temperature, lead me to the conclusion that a difference of 74·26 atmospheres on the manometer represents the variation of pressure corresponding to the condensation of oxygen in the tube immersed in the carbonic acid.

"This variation has been exactly observed in the last three experiments which I have made with the assistance of many of my colleagues here at Geneva.

"The quantity of liquid oxygen which we had in the tube was 45·467 grammes, corresponding to a volume of 46·25 cubic centimetres. But it is possible that the highest part of the thin tube had

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[1] Letter to M. Dumas. *Comptes Rendus*, Jan. 7th, 1878.

some centimetres in length not occupied by the liquid. This may explain the difference of 0·8 gramme found.

"Moreover, very volatile liquids have such considerable expansions that it is indispensable to have exactly the temperature to which they are subjected, in order to determine their true density. However this may be, there is an absolute verification, within small limits, of error of the theoretical calculation regarding this physical constant."

In addition to this important result, in another experiment, M. Pictet has used polarized light to determine the presence or absence of solid particles of oxygen in the jet. The jet was illuminated by means of the electric light, and observed with two Nicol prisms. A very strong polarization was observed, indicating the presence of solid particles, which in all probability were really solid particles of oxygen.

LIQUEFACTION OF HYDROGEN.[1]

By M. Raoul Pictet.

"*Geneva*, January 11th.

"I have the pleasure of giving you the result of an experiment carried out by me on the evening of Thursday, the 9th inst., with a view to liquefy and solidify hydrogen.

"This apparatus was exactly the same as that for the liquefaction of oxygen. I made use of nitrous oxide instead of carbonic acid.

"To obtain hydrogen under pressure, I decomposed formiate of potash with caustic potash. The hydrogen is given off without a trace of water, and the residuum is not volatile, two conditions essential to obtaining exact observations. The reaction has a well-defined temperature, above which it did not rise, the hydrogen being given off with perfect regularity, at a rate corresponding to 252 litres at zero. The pressure rose to 650 atmospheres before it stood still. The cold was about — 140° (I have not yet reduced the measurement of the temperature). On opening the stop-cock, the liquid hydrogen issued with vehemence from the orifice, making a piercing, whistling sound. The jet was of a steel-blue color, and was com-

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[1] Letter to M. Dumas. *Comptes Rendus*, Jan. 14th, 1878.

pletely opaque for a length of about 12 centimetres. At the same moment a sharp rattle was heard, similar to the sound made by falling gravel, and the whistling sound was changed into a peculiar hissing, resembling the noise made by a fragment of sodium when thrown on water. At almost the same moment the jet became intermittent, each pulsation of it being felt in the tap.

"During this first outrush of the hydrogen, the pressure receded from 650 to 370 atmospheres. On closing the tap, the pressure gradually fell for several minutes, reaching 215 atmospheres, from which it rose slowly to 225, where it remained stationary a second time. I opened the tap again, but the jet was so intermittent in its motion that it was evident the congelation of the hydrogen had been effected in the tube. This supposition, on my stopping the pumps and the freezing, was proved to be correct by the gradual outflow of all the hydrogen. The difference between these results and those I obtained for oxygen, I explain in the following way:

"Hydrogen has an atomic weight sixteen times less that of oxygen; the latent heat of hydrogen ought, therefore, to be ten times above that of oxygen. As soon as the outflow tap is opened, the liquid collected in the tube evaporates in part, absorbing so much heat in the change of state, that the remainder solidifies in the tube before being expelled.

"For more than a quarter of an hour we had successive discharges of hydrogen from the orifice of the tube. The mist produced by the expansion of the gases at the commencement of the experiment fell as low as the ground, ceasing completely as soon as the jet became intermittent, the phenomena corresponding to the congelation of the hydrogen in the interior of the tube.

"It is impossible to confound the vesicular mist of the gas with the appearance of the liquid jet seen at the beginning of the experiment. These various appearances are clearly distinguishable, and give rise to no sort of ambiguity. I know the volume of the residuum, and in a future experiment shall be able to determine the density of liquid hydrogen."

WATER SUPPLY OF THE STATE OF NEW JERSEY.

Report by the Committee on Water Supply, read at Meeting of New Jersey State Sanitary Association, held at Princeton, Oct. 17th, 1877.

By ALBERT R. LEEDS, Chairman.

We shall endeavor, as was done in report of last year,[1] to lay down certain general principles affecting the whole question of water supply. In the first place, it will be seen by an examination of the physical features of the state, that it is naturally divided up into a limited number of great hydrographical basins. By hydrographical basin we mean all that area, the rainfall of which finds its way down to the lowest level, by a connected system of greater and less tributaries, into one main water-course. Such, for example, is the Hackensack basin, the water-shed of which, including Rockland Lake, is 84 square miles, or together with Closter Brook, about 16 square miles, amounts in all to 100 square miles. The Passaic basin, which, including that of the Ramapo, 148, the Ringwood, 108, the Rockaway, 165 square miles, and other streams of less magnitude, amounts in all to 750 square miles. If we assume that the least annual rainfall is 30 inches, the entire bulk of water drained off the Passaic basin would amount to about 390 billions of gallons annually, or something more than one billion per diem. The drainage of the Hackensack basin is 52 billions of gallons annually. Similar remarks and calculations would apply to the Raritan and other basins, but are omitted from lack of immediate practical importance.

In the second place, it is a well-recognized law, that commodities attain their greatest value for purposes of exchange, when they arrive at the lowest practical point above sea-level, and hence great commercial centres are generally built up at the lowest points of such hydrographical basins, and usually at or near the mouth of their main water-course. In the early history of these commercial ports, the great river on which they are located brings them not only agriculture and trade, but also an apparently inexhaustible supply of pure drinking-water. At this period of development, their water-works are placed a few miles up the river beyond the town, and we notice as the first phase of the water supply system, Newark and Jersey City

[1] See "Recent Progress of Sanitary Science," *Amer. Chemist*, 1877.

pumping their supply from the Passaic, New Brunswick from the Raritan, Philadelphia and Camden from the Delaware, and so on.

In the third place, the development of agriculture and commerce is quickly followed by manufacturing industries, and every adequate waterfall in the hydrographical basin is seized upon for power; in the beginning, to turn the forests into timber; and, when the woods have been recklessly cut away, to grind grain, card and weave woolen fabrics, and, with increasing wealth, supply paper-mills and dye-works, bleacheries, silk-factories, all varieties of metal and chemical works, manufactories without number and of endless varieties, each sending downward its own burden of refuse—greater or smaller in amount, less or more pernicious. Exactly the nature and amount of this refuse, can be best learned from the elaborate statistics compiled by Mr. L. B. Ward, and published in the Seventh Annual Report of the State Board of Health of Massachusetts. A deliberate examination of Mr. Ward's figures teaches more forcibly than words, however strong, to what death-dealing consequences that pollution has now attained in some of the manufacturing streams in Great Britain, and may be expected to reach in this country, with the growth of our manufactures and the lack of repressive legislation. Neither could we do aught than injustice to a statement, itself condensed from the great mass of English reports, by attempting to epitomize it here. But, when we consider that in the manufacture of wool into fine cloth it passes through upwards of forty steps, in ten of which water is used, and greatly fouled almost as often as used, and that five parts in one hundred of the waste liquids are impurities, and of these, three parts are putrescible nitrogenous matters, we can form some faint conception of the pollution from this source alone. If we add to this, the vegetable dye-stuffs and the animal excrements, the acids and alkalies, the metallic salts—including even those of arsenic, employed in cotton manufacture—and, furthermore, the compounds of chlorine and sulphur, used in bleacheries, the rapidly decomposing waste products of tanneries, paper-mills, sugar-houses, starch-factories, and liquor-distilleries, we appreciate the magnitude of the polluting agencies which have long since killed all fish life in many European streams, and turned some into sewers, rolling down toward the sea a pestilential flood of foul-smelling liquids black as ink.

Moreover, there exists, along our Atlantic seaboard, a peculiar physical cause for the building of a large manufacturing town upon

the main water-courses, at a point somewhat above that at which the tidal city is located: the abrupt plunge from the hill country forming the upper portions of the hydrographical basin, down to the level of the alluvial or other recent formation lying along the sea-coast. Of this natural result, Paterson exhibits the most striking instance, and one which, at the same time, concerns us most nearly.

During all this period of transition, while the hydrographical basin is passing from an agricultural to a manufacturing territory, there are slowly growing up two quite antagonistic phases of popular opinion. The one, which is held mostly by dwellers in the hill country, by owners of mill sites and dam sites, by inhabitants of the water-power manufacturing towns, is that rivers were, to a large extent, beneficently designed to carry off sewage, filth of all kinds, and factory refuse. The other, which is in vogue among the greater number, those living near tide-level, is that rivers might, with greater fairness, be looked upon, not as sewers, but as gigantic aqueducts, designed by nature to supply, at small cost, dense centres of population with an adequate supply of pure drinking-water. This latter might, for sake of distinction, be styled the "City of New Jersey" opinion; the former, at least until a considerable manufacturing industry shall have developed itself at Little Falls, or some upper point upon the Passaic, the "Paterson" opinion. The force of gravity is upon its side.

There is another cause, which tends to aggravate the hardships of those living near tide-water. It arises from the destruction of forests, and the rude disarrangement thus effected in the exquisite machinery of nature's physical laws.

When these rain detainers and precipitants are gone, the clouds hurry by without yielding up their needed stores of rain. The streams falling during summer-heats below their natural level, expose stretches of aquatic vegetation to poison with malaria, or engender confervoid growths which slay the fishy inhabitants, and taint the drinking-water with foul taste and odors. Or, if the rain clouds, encountering sudden cold blasts, suddenly discharge their contents, with no forest growth to detain them, and no undergrowth of sedge and moss for their absorption, they rush backward to the sea, tearing up in their course, and irrupting into the stream, decaying matters or filth accumulations, which, under happier circumstances,

would either not at all, or only by gradual steps, find their way into the great water-courses.

Thus many things conspire to make a deplorable result. The remedial agencies of aeration and oxidation, which, in the natural economy of flowing streams, nature has provided in amount more than adequate to dispose of all natural sources of fouling, now long since taxed to their utmost capacity by the growing load of sewage and refuse, in these seasons of drought or freshet prove inadequate.

The river now has its periodical sicknesses, and the population its periodical scares. The chemist is called in, and shows not that the water is bad, neither, exactly, that it is good, but only that it is not much better or worse than the water supply of some other city, which, like the Schuylkill at Philadelphia, and the Thames above London, has been used without the population falling ill of violent maladies. The chemist also reveals the surprising fact, that this same water, taken before the sewage was put into it, such, for instance, as the Passaic before it has left the hill country, is of remarkable purity, and nothing could be wiser or better than to get possession of this water before some other men have used it and passed it on. Then the engineer is summoned, and, after many more months, presents his array of figures, unhappily not in decimals, but in millions, showing how much it will cost to bring the water pure from its fountain head. At a total so appalling, the populace takes fright; the matter is dropped, only to be revived when the next sickness of the water supply excites an other newspaper scare.

This second period is the era of make-shifts in the water supply. It is rife in projects intended to increase the amount and improve the quality from tidal waters. To this class of make-shifts belongs that now before the public of constructing a dam across the Passaic River, at Belleville, to keep back the tide-water and sewage of Newark, with suitable locks to pass boats navigating the river at that point. The objection that the water would still be polluted by the sewage of Paterson and Passaic, is met by the proposed construction of an intercepting sewer, terminating below the proposed dam.

Another make-shift is the purchase of the Dundee dam, and the building of an aqueduct thence to the present pumping works. This plan would also necessitate an intercepting sewer from Paterson.

The last and final period is that which may be termed the era of ultimate water supply. This is reached when the great commercial

towns despair of redress in the matter of sewage. The time may come, and it is to be earnestly hoped it is not far distant, when the growth of enlightened opinion may induce communities to exert all possible means to dispose, as far as possible, of their own sewage without detriment to others, and, deficient though they may have been hitherto in point of pecuniary success, yet every help, that science or public co-operation can afford, should be extended to schemes of sewage utilization. But for the present, permanent results are looked for only in the direction of the ultimate water supply—that is, drawing it from the upper portion of the hydrographical basins, at levels higher than will be probably utilized for agriculture, or densely populated by manufacturing industries. Such an ultimate water supply is that of the upper Hackensack basin, favorably reported upon, after an extended investigation, by James P. Kirkwood, C. E., and, at time of present writing, favorably entertained by the North Hudson Co. Water Commission as the best available supply for Hoboken and adjacent towns. It provides for the storage of a supply of 30,000,000 gallons per day, a conduit capacity of 20,000,000 gallons per day, and a pumping capacity of 10,000,000 gallons per day, at an outlay of $2,832,070. If Jersey City delays much longer in making the imperative improvement and increase of the common supply, this Hackensack plan will probably be adopted. The more so, since in one year, that ending May 1st, 1873, Hoboken paid to Jersey City for its share $75,815, exclusive of cost for distributing pipes or interest thereon, while the annual cost to Jersey City was $175,000, thus affording the latter city a considerable profit.

The City of New Jersey, meaning by this name all that large population of which the cities of Newark and Jersey City are the crowded centres, has discussed and caused to be extensively examined very many plans of ultimate water supply. A most valuable presentation of this part of the subject will be found in the annual report of the State Geologist for the year 1876, in which the director of the State Geological Survey, Prof. George H. Cook, summarizes the chemical and medical, the topographical, meteorological and engineering knowledge pertinent to this question. He has also contributed very numerous results of analyses and surveys of streams and ponds throughout the Passaic basin, which have rendered that knowledge more precise on many important particulars. The most noteworthy of these plans of ultimate water supply are six in number:

1. *The Little Falls Plan.*—This proposes, in case the water-power at Little Falls can be purchased, to employ it in raising the water a height of 50 feet, and sending in through a tunnel in the mountain at Great Notch. It admits of the use of the whole water supply of the upper Passaic basin.

2. *The First Mountain Reservoir Plan.*—This has a like advantage. In raising the water from a point near Little Falls, it is proposed to use steam-power; in distributing it, the force of gravity is relied upon to supply all the towns between Orange Mountain and the Hudson River.

3. *The Rockaway Plan.*—This proposes to bring the water of the Rockaway from near Denville, mostly by natural channels, to near Morristown, thence by piping to the high ground back of Madison and Chatham, then by tunnel to Millburn, where a head of 300 feet will permit of a gravity supply calculated at 60,000,000 gallons. It is stated by Prof. Cook, that this line is long, expensive, and would divert some streams from their present courses.

4. This plan, it is thought, could be advantageously modified by taking the water at Morristown through the ridge to Loantaka Brook, and thence in the natural channels to Chatham, from which it could be taken, at an elevation of about 200 feet, through the mountain to near Millburn. Calculated supply, 100,000,000 gallons per diem.

The four preceding plans contemplate drawing the ultimate water supply from the same hydrographical basin, as that in which the communities to be supplied are located. This appears to be a natural arrangement, and one which would have a further advantage if, in the increasing population of portions of the state, now sparsely settled, disputes might in equity arise, concerning the right of one community to use water apparently designed by nature for the water supply of another community, located in a distinct hydrographical basin.

Besides these four, there are two other plans of ultimate water supply, which propose the use, either wholly or in part, of the water supply of foreign hydrographical basins, viz.:

5. *L. B. Ward's Plan.*—The water of the Passaic is to be taken at or near Page's dam, above Chatham, and carried by tunnel through the mountain to Millburn. The supply of water could be increased by connecting the head waters of the Raritan, and, if needed, by opening the channel from the Rockaway at Berkshire Valley to the Black River, and from that across to Dead River and the

Passaic again. More than 100,000,000 gallons daily could be supplied in this way. The author of this plan has carefully elaborated the details, which are well worthy the study of those interested in the solution of this problem.

6. *The Morris Canal Plan.*—The waters are drawn from Lake Hopatcong, with a drainage area of 27 square miles, and altitude of 914 feet above mean tide, and Greenwood Lake, altitude 665 feet, and drainage area 32 square miles. It is stated in the report to the Newark Aqueduct Board, by the committee, of which John C. Campbell, C. E., was chairman, that the canal, as an open conduit, can deliver at the head of Bloomfield, at any season, a daily supply of thirty million gallons. It further states that the waters of the Rockaway, the Ramapo, the Ringwood, and the Pequanock, with a total of 463 square miles of drainage area (all of which is above the level of the canal, and in connection with it at Boonton and the head of the Pompton feeder), may be secured to increase the Morris Canal supply.

[To be continued.]

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[1]

By Dr. A. W. Hofmann.

From the *Chemical News*.

[Continued from Vol. lxxv, page 37.]

Nitrate of Potash.—For the manufacture of gunpowder, nitrate of soda is not adapted, on account of its hygroscopic nature. For this purpose it must be transformed into potash saltpetre. Hence large establishments have latterly sprung up for the manufacture of what is called, in contradistinction to the natural article, "converted saltpetre."

The industrial preparation of this converted nitre seems to have been undertaken almost simultaneously by Wöllner,[ii] Grüneberg,[iii]

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[1] "Berichte über die Entwickelung der Chemischen Industrie während des letzten Jahrzehends."

[ii] Wöllner, *Polyt. Notizbl.*, 1860, 49; *Wagner Jahresber.*, 1860, 204. *H. Grüneberg, Wagner Jahresber.*, 1869, 208.

[iii] H. Grüneberg, *Polyt. Notizbl.*, 1868, 968; *Wagner Jahresber.*, 1868, 288.

and Nöllner[i] about 1855, when a considerable demand for saltpetre suddenly sprung up in consequence of the Crimean war. Up to that date India and the native nitre-beds had supplied all that was required by the powder works. The importation of Indian saltpetre has latterly declined, and the manufacture of native saltpetre has come entirely to an end in England, France, and Germany, and is only now carried on upon a small scale in Sweden, Russia, and Spain.

The method now almost exclusively adopted for the production of converted saltpetre depends on the double decomposition of nitrate of soda and chloride of potassium, so as to yield nitrate of potash and chloride of sodium. Since the discovery and working of the deposits of potassium salts at Stassfurt the chloride of potassium is not merely the cheapest source of potash, but admits of the most complete decomposition.

As early as 1858, Anthon[ii] published a practical process for the manufacture of potash saltpetre from Chilian nitre and potassium chloride. In 1859 Kuhlmann[iii] reconsidered this method of manufacture, with especial regard to French requirements, and Waltl[iv] proposed to use the mother-liquor of brine springs or of sea-water, containing chloride of potassium, in the preparation of saltpetre.

A full description of the method of manufacturing converted saltpetre, as used in England in 1866, has been published by Lunge.[v] Equivalent weights of Chili nitre and Stassfurt potassium chloride—whose composition has previously been determined by analysis—are dissolved in water in large iron pans, and heated to a boil by the direct introduction of steam. The lye, after settling, is allowed to cool whilst constantly stirred, when the potash saltpetre is deposited as a fine crystalline meal, which is placed in wooden troughs lined with lead, and washed with water till a sample, on being tested with chloride of silver, contains only $\frac{1}{100}$ per cent. chloride of sodium. When the washing is completed, the still adherent mother-liquor is removed by means of centrifugals, and the saltpetre is then dried upon wooden surfaces in heated rooms. The mother-liquors are concentrated over an open fire, when the bulk of the common salt is deposited and

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i Nöllner, *Polyt. Notizbl.*, 1867, 370.

ii Anthon, *Dingler*, cxlix, 39; *Chem. Centralblatt*, 1858, 560; *Wagner*, 1858, 154.

iii Kuhlmann, *Bull. Soc. d'Encouragement*, 1859, 567; *Wagner*, 1859, 182.

iv Waltl, *Polyt. Central.*, 1859, 129; *Wagner*, 1859, 182.

v Lunge, *Dingler*, clxxxii, 385; *Wagner*, 1866, 223.

"fished out," whilst the liquid, on cooling, yields a further quantity of pulverulent saltpetre. In another establishment a solution of potassium chloride is first prepared, of specific gravity 1·200 to 1·210; in this the equivalent weight of Chili saltpetre is dissolved, and the solution is then concentrated over an open fire. The common salt which continually separates out is withdrawn, drained, and washed with water as long as it retains ½ per cent. saltpetre, the washings being returned to the pan. When the lye is concentrated to specific gravity 1·500, it is allowed to settle for a short time, when the common salt, as deposited, carries with it all dirt, and the clear solution is run into the crystallizers. By means of occasional agitation, the crystals are obtained as fine as those of Epsom salt: the mother-liquor is drawn off, and the crystals allowed to drain perfectly. They are then covered with cold water; after seven or eight hours the liquid is again drawn off, and after the crystals have drained for twelve hours, more water is poured on. This washing process is repeated till the desired purity is reached, which is generally the case after the second washing.

The author saw, in 1869, in a Scotch manufactory, this method so modified, that the dry salts, chloride of potassium, and Chili saltpetre, in equivalent proportions, were mixed and heated with a quantity of mother-liquor insufficient for complete solution. The operation was carried on in a number of iron cylinders, not very large, fitted with mechanical agitators, and heated with steam-jackets. The abundant aqueous vapors evolved were conducted through a lateral flue into the chimney of the works. After agitation for several hours, during which time the loss due to evaporation is constantly made up by fresh supplies of mother-liquor, the transformation is complete, the liquid contains the whole of the nitrate of potash in solution, and the solid salt consists of fine crystals of chloride of sodium. From the solution, clarified by settling, pulverulent saltpetre is obtained by disturbed crystallization, and freed by washing from adherent chloride of sodium. The salt is also washed in a similar manner till free from saltpetre. The mother-liquors and washing-waters are used in the treatment of fresh quantities of Chili saltpetre and chloride of potassium, and with careful working are said to be completely used up.

(To be continued.)

Lavoisier Medal.—The Société d'Encouragement pour l'Industrie Nationale has awarded its grand Lavoisier medal, for the progress of the chemical arts, to Walter Weldon, for his method of recovering chlorine from waste liquors. The consequent saving has reduced the price of chlorine 30 per cent.—*Les Mondes.* C.

Improved Telephone.—M. Trouvé has experimented, with a view to render the Bell telephone more sensitive, in order that satisfactory communications may be sent to greater distances than are now practicable. He substitutes a cube, or a polyhedron, with a vibrating membrane on each of the sides, so as to multiply the number of induced currents, and thus give the electric waves greater intensity.—*Les Mondes.* C.

Florentine Water-Works.—Among the most important enterprises of modern Italian engineering, are the new water-works of Florence. The object of the undertaking is thus stated in *Giornale del Genio Civile:* "To collect in a gallery, excavated near the city, the subterranean waters which filter through the sand and gravel which form the subsoil of the great valley of the Arno; to convey them into ample basins, from which, by means of powerful pumps, they may be distributed in canals, using the waters of the Arno and Corliss steam engines for motive force, and to establish ample reservoirs, above the level of the city, to receive the excess or supply the deficiency of hourly consumption, the reservoirs acting like the governors of a steam engine." C.

Temperature and Efficiency of Nitro-Glycerine.—Although the temperature developed by the combustion of nitro-glycerine has not been accurately measured, there is reason to believe that it is more than twice as great as that of gunpowder. A volume of powder produces, at the ordinary temperature, 190 volumes of gas; in consequence of the heat liberated, this gas is expanded to four times its volume, yielding 760 volumes of gas immediately after the explosion. A volume of nitro-glycerine produces 1300 volumes of gas at the ordinary temperature; in consequence of the heat set free, the expansion is supposed to reach 13000 volumes. At the slate quarries in the north of Wales, nitro-glycerine has been employed for a considerable time, and a single explosion accomplishes as much as four or five explosions with powder. Equally favorable results have been obtained at Freyberg and in Belgium.—*Revue Industr.* C.

Strength of Cast Steel.—As a proof of A. von Gautier's statement, that the strength and ductility of steel are increased by heating and subsequent slow cooling, von Tunner experimented with No. 4 Inneberg manganese-steel. His experiments were satisfactory, but he obtained still better results by hammering, rolling, or pressing the reheated steel.—*Kärnthn. Zeitsch.* C.

Protection of Bank-Notes against Fire.—A German inventor has devised a bank-note album, with leaves of asbestos-paper, for the protection of notes, checks, and valuable documents. By placing them between the asbestos leaves, especially if the book is firmly clasped, they may be kept legible, even after exposure to a fire which reduces them to cinders.—*Papier-Zeitung.* C.

Globular Lightning.—M. G. Planté has experimented upon distilled water with an electric current of high tension, by joining 20 secondary batteries, of 40 couples each, producing a current about equivalent to 1200 Bunsen elements. He thus produces a number of beautiful luminous effects, constituting "a true electric kaleidoscope;" imitates the phenomena which result from the fall of liquid drops on a plain surface, and shows that, with a sufficient quantity and tension of electricity, we can obtain not only electrized liquid globules, but even the electric spark itself in globular form.—*Comptes Rendus.* C.

Chemical Changes in Works of Art.—S de Luca describes six bronze goats, with lead bases, found in Pompeii. They were evidently designed for weights. The lead has been mostly changed into an amorphous mass of white carbonate. On the one-pound weight a portion has became translucent and partially crystalline. On the ten-pound weight there are definite crystals of carbonate, with a brilliant lustre. Their formation, in a period accurately known, is noteworthy.—*Comptes Rendus.* C.

Tunnel under the English Channel.—The experimental works at Sangatte are well under way. The shaft is already sunk to a depth of 100 metres below low water mark. Two pumps are employed to remove the water, which flows abundantly. A trial gallery has been begun, in the chalk, under the sea, perpendicular to the shaft. It is to be 1 kilometre long, and, if no difficulties arise during its completion which show that the work is impracticable, the tunnel will be promptly begun.—*Les Mondes.* C.

Artificial Corundum and Silicate Crystals.—MM. E. Fremy and Feil have been very successful in producing alumina crystals, especially rubies and sapphires, in masses sufficient to be used for clocks, and cut by lapidaries. They have often operated on 20 or 30 kilogrammes of materials at a time, which were subjected to an intense temperature, without interruption, for twenty days. They begin by forming a fusible aluminate, and heating it to a bright red, with some silicious substance, when the aluminum slowly separates from its saline combination, in presence of the flux, and crystallizes. Their paper mentions four different causes of crystallization; their best results, however, have been obtained with aluminate of lead. They describe the method of preparation for white corundum crystals: for rubies, they add 2 to 3 per cent. of bichromate of potash; for sapphires, a small quantity of oxyd of cobalt, mixed with a trace of bichromate of potash. Their rubies scratch quartz and topaz; their density is 4 to 4·1; like natural rubies, they lose color under intense heat, and resume it upon cooling; lapidaries have often found them even harder than natural rubies; they rapidly wear out the best grinding wheels of tempered steel. By submitting to a red heat, for many hours, equal weights of silex and of aluminum-fluoride, they obtain a fluoride of silicium and a crystallized body resembling *dysthène,* or silicate of aluminum. Other artificial silicates are also described.—*Comptes Rendus.* C.

Underground Telegraphs.—On the 23d of July, 1877, the underground telegraph line was completed between Berlin and Mainz, by sinking a river-cable in the Rhine, between Mainz and Castel. This is the longest underground line in the world (about 600 kilometres). A special incentive to the costly undertaking was the desire to guard the main line of German telegraphs against the frequent accidents and interruptions to which air lines are exposed, and the expense for repairs which they often entail. As an illustration of such expense, Wohlfahrt states, in his description of the line (*Dingler's Pol. Jour.*, 226, 363), that in the storm which occurred during the night of March 12-13, 1876, on the government telegraph lines there were 1073 poles broken, 9372 poles displaced or overthrown, 1696 stays and anchor-posts torn out, while the wires were broken in 1631 places, and twisted in 729 places. Consequently two-fifths of all the lines, or 52,390 kilometres, were partially useless for many days. The merely provisory repairs of this single night's

damage cost 44,000 marks, and the indirect loss to trade and commerce was incalculable. In times of a political crisis, or at the outbreak of a war, such widespread interruption to customary intercourse might be attended with the most serious consequences. C.

Artificial Feldspars.—M. Hautefeuille produces tridymite, orthoclase and triclinic feldspars, by exposing a mixture of silex and alumina, in presence of acid tungstate of potash, to a temperature between 900° and 1000°. If the potassa and alumina have been properly proportioned, the tridymite and triclinic feldspars soon disappear, and their elements increase the crystals of orthoclase. After fifteen to twenty days' heating, these crystals remain alone, and they may be easily separated, since the tungstate is soluble in boiling water. If soda is substituted for potash, the crystals are of albite. The committee to which M. Hautefeuille's paper was submitted (MM. H. Sainte-Claire Deville, Des Cloizeaux, and Daubrée) recommend its publication in the *Recueil des Mémoires des Savants Etrangers.* C.

Utilization of Waste Gases.—M. L. Cailletet has been studying the composition and the industrial employment of the gases which circulate in the hottest part of puddling furnaces. He finds a considerable proportion of carbonic oxide, and a large quantity of minutely divided carbon, so that, even after their passage under steam generators, the gases retain an important quantity of combustible materials, which can easily be rekindled and nearly all consumed, by the help of processes which he has described.—*Comptes Rendus.* C.

Engraving on Glass by Electricity.—M. G. Planté, whose electric experiments on glass and crystal have been already noticed in the JOURNAL, covers a surface of glass or crystal with a concentrated solution of nitrate of potash, by simply pouring the liquid on the plate, placed horizontally on a table or in a shallow dish. In the liquid film and along the borders of the plate he lays a platinum wire communicating with the poles of a secondary battery of 50 to 60 cells, then holding in his hand the other electrode of platinum wire surrounded, except at the end, by an insulating sheath, he touches the glass covered by the thin film of saline solution, at the points which he wishes to engrave. A luminous notch is made wherever the electrode touches, and however rapidly one writes or draws, the

marks are found sharply engraved on the glass. In writing or drawing slowly, the marks are engraved deeply; if the wire, which serves as electrode, is sharpened to a point, the lines may be made extremely fine. Either electrode may be used as a graver, but a weaker current suffices for the negative electrode. Although these results have been obtained by using secondary batteries, it is evident that any other source of electricity of sufficient quantity and tension, might be employed for continuous work, such as a Bunsen pile of a sufficient number of elements, or a gramme machine, or even a magneto-electric machine with reciprocating currents.—*Comptes Rendus.* C.

Caucasus Railway.—Herr von Statkowski, Russian Imperial State Councillor and Chief Inspector of the Swiss Poti-Tiflis Railway, has prepared plans for a road over the Caucasus, by the Maga Pass. The principal tunnel will be 6541·6 metres long; the next in length, 1167 metres; the aggregate length of 84 other tunnels, 12,960 metres.—*Zeits. des Oester. Ing.- und Arch.- Vereins.* C.

Early Paper.—M. Charles Schmidt publishes an account, in the *Bulletin de la Société Industrielle de Mulhouse*, of the water-marks upon paper used in Strasbourg, from 1343 to 1525. The earliest paper was made of cotton. The Arabs introduced it into Spain and Italy, whence it spread into other European countries. It was too soft to be durable. Paper made of old linen rags is first mentioned in 1120, by Peter, the Venerable Abbé of Cluny, who speaks of it as among the well-known materials for book-making. The machinery which was employed in Alsace in the fourteenth century, consisted of a mill-wheel for driving the piles, which reduced the rags to pulp, a vat, some moulds made of a tissue of wire, surrounded by a wooden frame, squares of felt for drying the sheets, and a sizing apparatus. Before A. D. 1400, at least twenty different factories were in operation. C.

Dry Graphite for Steam Cylinders.—Mr. W. J. Williams, engineer, 611 St. John St., Phila., has called my attention to the successful use of dry pulverized graphite for lubricating steam cylinders. He applies 137 grains twice a day, introducing it into the cylinder through the usual form of tallow-cup. Six months of continuous use, in an $11'' \times 30''$ horizontal engine, working to its full capacity, prove this lubricant superior in every way to oils or tallow, both of which he had used for years. No oil whatever is introduced with

the graphite. Besides satisfying all the lubricating needs of the cylinder, the joints, where gum is used, last longer, and show less of leakage. At 30 cents per pound, this engine would require $1\frac{1}{6}$ cents' worth per day. J. H. C.

Improved Method of Managing Steam-Boiler Fires.—When the furnace-door of a steam boiler is opened, there should be a simultaneous partial closing of the damper to prevent sudden chilling of the boiler and flues. To accomplish this, with certainty, for every opening of the doors, Mr. Wm. Weightman, of Powers & Weightman, has had arranged and applied a system of levers and rods, connecting the furnace-door with the damper, so contrived that whether there be one or more doors to one furnace, or to which one damper is supplied, the act of opening any one door will invariably close the damper. Whether this application of simple and ingenious devices is new, or not, every engineer will regard it as one of the good things for aiding the better management of steam-boilers.

J. H. C.

New Leveling Device.—Every millwright experiences difficulty in leveling shafting, when pulleys, hangers, walls, etc., are in the way of applying the "straight edge" from bearing to bearing which it is desired to bring to a level. Mr. Geo. Jennison, millwright at Powers and Weightman's, has adapted a very simple and readily applied apparatus, which can be used without the usual "level boards" and "straight edges," and without regard to the obstructions in the way.

He takes an ordinary $\frac{3}{8}''$ or $\frac{1}{2}''$ gum tube, say 16 or 20 feet long, and to each end secures a stout glass tube 10″ to 12″ long; fills the gum tube with water to within, say, 4″ of each end of the glass tubes, puts a cork in each, and the apparatus is complete. To use this, hold each glass vertically at the bearings, and withdraw the corks; the water will soon find its level, and show how the bearings stand with regard to the level line. J. H. C.

The Liquefaction of Gases, and the Artificial Production of Low Temperatures.—In the JOURNAL OF THE FRANKLIN INSTITUTE for January, 1874 (p. 9), will be found a brief notice, by Prof. E. J. Houston, of a German refrigerating machine, proposed for making ice. Prof. Houston, after commenting upon the method of employment of the cold of expansion as the agent for the removal

of heat from compressed air, suggests modifications of construction of the apparatus, "which would render its cold producing power almost unlimited," and he says, in conclusion of his notice, that the great scientific advantages to be expected to accrue from the modified apparatus, are the following:

1st. The confirmation or otherwise of the "absolute zero," as determined by the expansion or contraction of gases by heat or cold.

2d. The liquefaction and subsequent solidification of many of the incoercible gases, the determination of their physical peculiarities as liquids or solids, together with their crystalline form.

3d. The action of intense cold on the chemical affinities of certain gaseous compounds.

4th. The action of intense cold on the color of certain chemical compounds.

The methods proposed by Prof. Houston were those followed by the two eminent chemists, Pictet and Cailletet, in their recent accomplishments in liquefaction of gases. The complete determination of the four problems must follow these results in time. The eventual liquefaction, and perhaps solidification, of all gases, has been anticipated as a probability by most chemists and physicists.

Prof. Houston's article of four years since, anticipated the way in which it has been done. .B.

The Reaction Principle in Dynamo-Electric Machines.—Quite an extended controversy has recently been carried on through the columns of *Engineering*, between Dr. C. W. Siemens and Mr. S. A. Varley, in regard to the relative claims of the latter, and of Dr. Werner Siemens, to priority in the discovery and application of the reaction principle in dynamo-electric machines.

The following extract from a letter of Mr. Robert Sabine, published in the same journal, appears to give a fair statement of their respective claims, and also those of Professor Wheatstone, and serves as another illustration of how frequently it occurs that several persons are at the same time pursuing independently the same investigation, and arrive at the same results, at dates, the intervals between which are too small to entitle any one of them to all the credit. In this case the honors seem about evenly divided.

* * * "In the little controversy which has been going on, the claims of the late Professor Wheatstone have been, to a great extent,

inadvertently passed over. I therefore hasten to supply the omission as far as I am able.

"At what date 'the idea of making a machine which would work into itself occurred to' Professor Wheatstone, it is, of course, after his death, impossible to determine, unless some manuscript notes should turn up in evidence. I am also unable to ascertain when his *first* experimental apparatus was made and tried. We must therefore start from the later stage, viz., the finished machines which were exhibited at the Royal Society in February, 1867.

"These machines were made for Professor Wheatstone by Mr. Stroh in the months of July and August, 1866. When they were finished, tried, and approved of, they were, in the usual course of business, charged for by Mr. Stroh on the 12th of September, 1866.

"Mr. S. A. Varley says his 'machine (as it was exhibited in the Loan Collection) was completed and tried at the end of September, or the beginning of October, 1866.'

"Dr. Siemens says that his brother 'tried his first experimental machine in December, 1866.'

"It is clear, therefore, that Professor Wheatstone's machines—those exhibited at the Royal Society—were completed, tried, and charged for before the first experimental machines of either Dr. Siemens or Mr. Varley were finished and ready for trial.

"The date when an undefined idea of making any machine first occurs to an inventor is of very little comparative importance, unless the idea be productive of some evidence of its being, without which one would naturally be inclined to suspect that memory might after the lapse of years be a little treacherous. Who had the first happy inspiration of a reaction machine, we can scarcely expect to know now. Of its fruits we have better evidence, and I venture to think that the claims of the three inventors in question stand thus:

"Professor Wheatstone was the first to complete and try the reaction machine.

"Mr. S. A. Varley was the first to put the machine officially on record, in a provisional specification dated the 24th of December, 1866, which was, therefore, not published until July, 1867.

"Dr. Werner Siemens was the first to call public attention to the machine, in a paper read before the Berlin Academy, on the 17th of January, 1867." *

New Safety Heating Apparatus for Cars.—Among the most fruitful causes of loss of life in railroad accidents, is the burning of cars, which take fire from the stoves or other heating apparatus contained in them. In order to reduce the risk as far as possible, Messrs. Wood, Scull & Snyder, of this city, have devised a plan for heating the cars with steam generated in a boiler provided especially for that purpose, and placed in the baggage or smoking car.

The distribution of the steam-pipes in the cars, for heating, is well arranged, and contains some points of novelty. The essential feature of the apparatus, however, lies in the flexible joints in the pipes connecting the cars. These are so constructed as to yield freely to all the movements of the cars and yet remain tight, and are entirely self-acting in coupling and uncoupling.

This arrangement has been in constant use on the Camden and Atlantic Railroad for more than three months, giving great satisfaction. It is clear, that there being but one fire in the whole train (outside of the locomotive), and that at a considerable distance from the passengers, the risk of life from fire, in case of a "smash-up," is greatly reduced. It is also claimed that this arrangement is more economical in fuel, labor and maintenance than the best device for heating each car separately.

Drawings of the flexible self-coupling device, which renders this system practical, are promised us soon for publication. *

Engineers' Club of Philadelphia.—A society has recently been formed by the younger engineers of Philadelphia, having for its object the professional improvement of its members, encouragement of social intercourse among men of practical science, and the advancement of the various branches of engineering. Meetings for the discussion of scientific subjects and the reading of professional papers are held for the present at the residences of the members, on the first and third Saturdays in each month. The society is called the Engineers' Club of Philadelphia, and was formally organized on Monday, December 17th, 1877, when the following officers were elected:—President, Prof. L. M. Haupt; Vice-President, Coleman Sellers, Jr.; Secretary and Treasurer, Charles E. Billin.

Book Notices.

ELEMENTS OF THE METHOD OF LEAST SQUARES.—By Mansfield Merriman, Ph. D., Instructor in Civil Engineering in the Sheffield Scientific School of Yale College. London: MacMillan and Co., 1877. 12mo., pp. 200. For sale by J. B. Lippincott & Co.

Our readers have already become acquainted with Dr. Merriman's name, in connection with the subject of least squares, through his articles in the September, October and November numbers of the JOURNAL, for 1877. In the preface to his "Elements," he says:

"In writing the following pages I have had two objects in view: first, to present the fundamental principles and processes of the Method of Least Squares in so plain a manner, and to illustrate their application by such simple and practical examples, as to render it accessible to civil engineers who have not had the benefit of extended mathematical training; and secondly, to give an elementary exposition of the theory which would be adapted to the wants of a large and constantly increasing class of students."

These objects are both accomplished, so satisfactorily, that those who have had no experience in the practical use of this method, can soon make themselves familiar with some of its most useful applications. They will thus gain a ready means of simply formulating their results, so as greatly to enhance their value.

Even expert mathematicians, who have never made themselves thoroughly acquainted with the theory, but have only occasional calls for its use, will find the manual a convenient one for handy reference, to refresh their memory upon points which may be easily forgotten when out of practice. C.

THE MECHANICS OF ENGINEERING AND THE CONSTRUCTION OF MACHINES. By Dr. Phil. Julius Weisbach. Vol. II, Application of Mechanics to Machines. Translated from the fourth augmented and improved German edition, by A. Jay DuBois, Ph. D. 8vo, pp. 668. New York, John Wiley & Sons, 1877.

The long anticipated American translation of the second volume of Dr. Julius Weisbach's celebrated "Manual of the Mechanics of Engineering and the Construction of Machines," has at length appeared from the press of John Wiley & Sons, New York, and is about uniform in shape and appearance with Vol. I, published some years ago by Van Nostrand. Van Nostrand's Vol. I, a book of over

1100 pages, comprises the whole of Weisbach's first volume, as it appears in the fourth and latest German edition, and was translated by Mr. Eckley B. Coxe, who intended to complete the entire work in two additional volumes. Professional business, however, seems to have prevented the consummation of Mr. Coxe's design, as he finally relinquished the task to Prof. A. Jay DuBois, of the Sheffield Scientific School of Yale College, to whom we are, therefore, indebted for the translation now offered us. Dr. Weisbach's Vol. II (fourth German edition) is divided into two sections, the first treating of the application of the mechanical principles set forth in Vol. I, to structures of stability—such as roofs, bridges, retaining walls, etc. Prof. DuBois, deeming the subject already over-written, entirely omits this portion of the work, and begins his translation at the second section, which treats of the application of the mechanical principles to machines. This section is subdivided into two parts, discussing, first, the various motive powers and their reciprocal machines, hydraulics and air motors, etc.; and secondly, heat, the steam engine, etc.

Part first of Weisbach's second volume forms the subject matter of Prof. DuBois' work (Vol. II of the American translation), and he promises soon to give us a second volume (Vol. III. of the series), which will complete Weisbach's second volume, by giving us the remainder of his Section II. In order to add to the completeness of his book, Prof. DuBois has prefaced it with an introduction of 53 pp., briefly rehearsing those principles set forth in Vol. I which are most frequently referred to in Vol. II. He discusses here, in a more or less general way, such topics as work, effective delivery, unit of work, inertia, momentum, velocity, acceleration of gravity, *vis viva*, impart, centrifugal force, etc., and gives the formulæ most often required in the pages to follow.

This introduction, although in part made up of selections from Vol. I, is very largely composed of new matter from the pen of Prof. DuBois, who arrives at Weisbach's results by new methods, and gives his own definitions and descriptions in exceptionally clear and concise terms. Prof. DuBois, in his introduction, has not confined himself exclusively to Weisbach's investigations, but has availed himself of the results obtained by the labors of more recent investigators; and his addition makes the book complete and self-contained, and enables it to be used satisfactorily without a constant reference to the previous volume, and, indeed, will possibly permit it to be employed as a college text-book, even to the exclusion of Vol. I.

Prof. DuBois, in thus rendering accessible to the English-speaking public so valuable a book, has made a very important addition to our technological library; and it is most sincerely to be hoped that he may be enabled to prosecute his labors until the whole of Dr. Weisbach's great work is reduced to English language and nomenclatures.

S.

Franklin Institute.

Hall of the Institute, Feb. 20th, 1878.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

There were present 132 members and 26 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 12 persons were elected members of the Institute, and the following donations were made to the Library:

Reports of the Hartford Steam Boiler Inspection and Insurance Company. 1873 to 1876 inclusive. From the Company.

Monthly reports on the Commerce and Navigation of the United States. By Edward Young. For fiscal years ending June 30th, 1874-5.
Quarterly reports of the Chief of the Bureau of Statistics, for 1875-6 and 1876-7.
Annual report of the Chief, for fiscal year ending June 30th, 1876.
First annual report on the Internal Commerce of the United States. By Jos. Nimmo, Jr. Or Part 2d of report of Chief of Bureau of Statistics, etc.
Rapport special sur l'imigration, etc. Par E. Young, 1872.
List of Merchant Vessels and Vessels of the U. S. Navy and Revenue Marine service, 1876. From the Chief of Bureau.

Reports of the Chief of Ordnance to the Secretary of War, for 1872-3, and 1875 to 1877, inclusive.
Ordnance Memoranda, No. 14, 17 to 20, Washington, 1873-77. From Chief of Bureau.

Pennsylvania Archives, Second Ser., Vol. 5th, Harrisburg, 1877. From Historical Society, Penna.

Phœnix Iron Company, Album of Iron Manufactured. From the Company.

Meteorological Observations, made at the U. S. Naval Observatory, during the year 1875. From Naval Observatory.

An address on the Endowment of Research. By E. C. Pickering. Salem, 1875. From the Author.

Circulars of information of the Bureau of Education, Nos. 1 and 2, 1877.

Contributions to the History of Medical Education and Medical Institutions, in the U. S. of America, 1776 1876. Special report of N. S. Davis. Washington, 1877. From the Bureau of Education.

Whittaker's Compound Pitch, True Screw Propeller. Letters Patent, 1877. From W. P. Street.

Des Paratonnerres à pointes, à conducteurs, etc. Par M. Meslens. From the Author.

American Engines and Fairlie Engines compared. By W. W. Evans. From the Author.

Reply to criticisms made by Dr. Hagen, of Germany, on the Physics and Hydraulics of the Mississippi. By Humphries and Abbot. From Chief of Engineers.

The Pennsylvania Railroad; its origin, construction, condition, etc. By W. B. Sipes. Phila., 1875. From P. L. Farmer, Gen. Pass. Agent.

Message of the President of the United States, containing reports of Secretary of the Navy and Postmaster-General, for 1866.

Essay on the use of various Alloys for founding Cannon. By Levy and Runkle, Brussels, 1870. Translation. Washington, 1872.

Annual report of the Secretary of the Navy, on the Operations of the Dept., for the year 1871. From the Secretary of the Navy.

Annual report of the Secretary of the Treasury, on the state of the Finances, for the year 1877. From the Secretary of the Treasury.

Annual report of the Chief of Engineers for the year 1877, in two parts. From the Chief of Engineers.

Rules of practice in the United States Patent Office, Aug., 1877. From the Commissioner of Patents.

Annual report of the Director of Harvard College Observatory. Cambridge, 1877. From E. C. Pickering.

25th annual report to the Council of City of Manchester, on the working of the Public Free Libraries, 1876-7. Manchester, 1877. From the Council.

An inquiry into the state of the Ancient Measures. By B. P. Hooper. From W. P. Tatham.

The Actuary also reported that at the last meeting of the Board of Mânagers, Prof. Robert H. Thurston, of Hoboken, N. J., was unanimously nominated for election as a corresponding member of the Institute.

Mr. Henry P. M. Birkinbine then read the paper announced for the evening, being on "The Future Water Supply of Philadelphia."

The Secretary presented his report, embracing illustrated descriptions of the method employed by Mr. James P. Davis for moving a large brick house; Edgerton's new apparatus for carburetting air for illumination; Grace Spark Arrester; Sommers' Differential Valve; and a specimen of the brass tubes of the surface condenser of one of the Pacific Steamers, which were badly corroded at the point where they were fastened in the tube sheets with wooden ferrules.

Mr. Hector Orr made some remarks on the loss of two highly esteemed and useful citizens, both of whom have long been members of the Institute, and presented the following resolutions, which were unanimously adopted:

Resolved, That by the death of JOHN WIEGAND, ESQ., we lose an early member and efficient friend of this Institute, an accomplished mechanic, and highly useful citizen, who has discharged the various duties, public and private, of a long life, with honor to himself and benefit to his fellow men. We here emphatically acknowledge our loss, and commend his example to all survivors.

Resolved, That the Franklin Institute hereby records its testimony to the loss sustained by it and this community, and the nation at large, in the death of our late member, WILLIAM WELSH, ESQ., who, after a long term of absence, had recently returned to a most gratifying activity in our midst, who leaves unfinished much work which seemed adapted to his hand, and makes a vacancy in our ranks that we cannot hope soon to fill. Joining in the universal eulogium of the public, we bid him farewell, and repeat to each other the words of Edmund Burke: "Revere—imitate—persevere!"

An amendment to the by-laws, proposed by Mr. W. P. Tatham, by the substitution of the following for the existing Art. XVI, was read, and laid over to the next stated meeting:

Amendments to these by-laws to be proposed at any stated monthly meeting, shall be posted upon the notice board by the first of the month. Such proposition, when presented to the meeting, may be considered, amended, referred, postponed or rejected, or ordered to be published weekly in two or more daily papers published in the City of Philadelphia, by a majority vote.

At a subsequent stated meeting, after such publication, the amendment may be adopted by a vote of two-thirds of the members present, except in the case of Art. I, relating to capital stock, which cannot be altered unless by a vote of a majority of the stock represented.

On motion of Mr. H. Cartwright, Prof. Robt. H. Thurston was unanimously elected a corresponding member of the Institute.

The following letter, in response to a copy of the resolutions on the subject,[1] adopted at the last meeting, was read:

"OFFICE BOARD OF SUPERVISING INSPECTORS,
WASHINGTON, D. C.

"*January 26th*, 1878.

"To J. B. KNIGHT, ESQ., *Sec. of the Frank. Ins.*, Phila., Pa.

"SIR:—In reply to your communication of Jan. 17th, addressed to the Board of Supervising Inspectors, I am instructed to state to you that under the law of February 28th, 1871, regulating the inspection of steam vessels, no such brand as "C. H., No. 1 shell," is required, and that, practically, no such brands are in use.

"Under the present law, the only stamp required on boiler iron is the name of the manufacturer and the tensile strength, and nothing in the law prevents the lower grades of iron from being used, so long as the plates are properly and plainly stamped as above described.

"Very respectfully,

"B. O. CARR (Super. Inspec. 6th Dis.),
"*Secretary.*"

The President announced the following standing committees of the Institute for the current year:

On Library.—Chas. Bullock, W. P. Tatham, Jos. M. Wilson, Robert Briggs, J. B. Knight, E. J. Houston, J. W. Nystrom, Dr. Isaac Norris, Jr., J. E. Mitchell, John H. Cooper.

On Minerals.—Dr. F. A. Genth, Theo. D. Rand, Clarence Bement, Persifor Frazer, Jr., Dr. W. H. Wahl, E. J. Houston, Otto Luthy, E. F. Moody, Dr. G. A. Kœnig, H. Pemberton, Jr.

On Models.—C. Chabot, H. L. Butler, Edward Brown, M. L. Orum, J. Gœhring, L. L. Cheney, J. J. Weaver, S. Lloyd Wiegand, A. G. Busby, N. H. Edgerton.

On Arts and Manufactures.—J. J. Weaver, Geo. V. Cresson, Hector Orr, Coleman Sellers, Jr., W. B. LeVan, Wm. Helme, J. S. Bancroft, Alfred Mellor, Cyrus Chambers, Jr., Geo. Burnham.

On Meteorology.—Pliny E. Chase, Hector Orr, Dr. Isaac Norris, Jr., John Wise, Jas. A. Kirkpatrick, Alex. Purves, Dr. W. H. Wahl, F. M. M. Beale, H. Carville Lewis.

On Meetings.—H. Cartwright, Washington Jones, J. B. Knight, C. S. Close, W. P. Tatham, L. M. Haupt, W. L. DuBois, W. H. Thorne, Cyrus Chambers, Jr.

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary.*

[1] See page 144, this volume.

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VOL. CV. APRIL, 1878. No. 4.

COAL GAS ENGINEERING.

By ROBT. BRIGGS, C.E.

COMMON COAL GAS—ITS COMPOSITION, AND RESULTS OF COMBUSTION.—Some forty or more distinct gaseous chemical components are well known to have existence in the ordinary coal gas of the gas works, in four several groups: the first of which are gases which burn in air without, or with slight, emission of light; the second, gases which, when burned with the first for supply of heat, evolve carbon, which, becoming incandescent before burning itself, emits light; the third, incombustible gases; and the fourth, gases which are considered impurities. The first group is over four-fifths of the volume of coal gas, and is composed of only three substances or compounds, to wit: hydrogen, marsh gas and carbonic oxide; the second, which is only 7 to 9 per cent., comprises an almost endless list of hydro-carbon compounds, which are diffused, as gases or vapors, into the gases of the other groups; for the purpose of this paper this group will be con-

sidered as if composed entirely of olefiant gas (possibly most of these hydro-carbons are of the olefine series of compounds); the third comprises the carbonic acid, aqueous vapor and air, and is always 3 to 6 per cent. of coal gas; while the fourth, the impurities—ammonia and sulphur compounds; obnoxious as they are in quality, in any tolerably well purified gas the percentage of them in volume is so small, that in a discussion of results of combustion they do not become an element.

With this explanation to qualify the following statements and calculations, it is proper to say that common coal gas, of 14 to 15 candles illuminating power, has the following constituents in volumes per hundred parts: Hydrogen, H, 44 to 48; marsh gas, CH_4, 34 to 38; olefiant gas, C_2H_4, and other hydro-carbons, etc., 6 to 9; carbonic oxide, CO, 5 to 7; carbonic acid, CO_2, 1 to 3; air, $4N+O$, 1 to 3; aqueous vapor, H_2O (saturation at 40° to 60°), 1 to 2. The specific gravity of coal gas is about 0·426, which makes the volume of a pound of gas at 70° (barometer 29·9 in.) equal to 31·3 cubic feet (neglecting fractions, too small to be of consequence in this estimate) = 0·0319 lb. per cubic foot. Taking an average of the constituents of coal gas by weight, they can be reduced to 21·8 parts of hydrogen, 51·3 parts of carbon, and 13·6 parts of carbonic oxide, which are combustible; leaving 13·3 parts of non-combustible substances. The figures of the reduction of volumes to weights are as follows:

	Constituents.	Volumes per ct.	Do. average.	Specific Gravity.		H.	C.		Wt.	per ct.
H	Hydrogen,	44 @ 48	45	0·0692 =	3·114	3·114		H	9·266	21·8
CH_4	Marsh gas,	34 @ 38	36	0·559 =	20·124	5·031	15·093			
C_2H_4	Olefiant gas,	6 @ 9	8	0·981 =	7·848	1·121	6·727	C	21·820	51·3
CO	Carbonic oxide,	5 @ 7	6	0·967 =	5·802				5·802	13·6
CO_2	Carbonic acid,	1 @ 3	2	1·524 =	3·048				3·048	7·2
$4N+O$	Air,	1 @ 3	2	1·000 =	2·000				2·000	4·6
H_2O	Vapor of water,	1 @ 2	1	0·622 =	0·622				0·622	1·5
			100		42·558	9·266	21·820		42·558	100·

From these data, the heat given out by *complete* combustion can be calculated—hydrogen gas will evolve in its chemical change to vapor of water (including the latent heat of the vapor) 62,000 units of heat, while carbon, in becoming carbonic acid, evolves 14,500 units, and carbonic oxide, in changing to the same form, evolves 4330 units—with the following result:

Combustion of 100 Pounds of Coal Gas.

Combustion.		Oxygen required.	Air required to supply oxygen.	Air required to effect complete combustion.	Units of heat per lb. of combustible	Units of heat total evolved.	Product. H_2O	Product. CO_2
H	21·8	174·4	785	1570	62000	1351600	196·2	
C	51·3	136·8	616	1232	14500	743850		188·1
CO	13·6	7·8	35	70	4330	58890		21·4
CO_2	7·2	0·						7·2
4N+O	4·6	0·						
H_2O*	1·5	0·					1·5	
	100·	319·	1436	2872		2154350	198·	217·
Deduct latent heat of 196·2 lbs. vapor of 70° @ 1065°,						208950		
Total units of heat from 100 lbs. coal gas (86·7 combustible + 13·3 of non-combustible)........................						1945400		

[* This ratio of vapor of water corresponds to the condition of vapor in saturated air at the temperature of 43° or 41 per cent. humidity at 70°—perhaps a little dry for summer tests.]

Accepting these quantities for the products of combustion of 100 pounds of coal gas, the absolute temperature attained may be estimated. Three different hypotheses present themselves: the first supposes the absolute heat to be that derived from the capacity of the product to take up the entire heat generated. The second limits the expenditure of heat in producing intensity, to the air needed to supply oxygen; while the third supposes the ultimate maximum intensity to be that derived from the chemical combination of oxygen and carbon, and of oxygen and hydrogen. The last is probably the correct value for the *intensity* of the source of radiating heat from a gas light. The following table gives the three computations in the order named:

	Pounds × Specific heat = Sum of weight multiplied by Specific heat.		Pounds = sum, etc.		Pounds = sum, etc.
H_2O	198 × 0·478 = 94·050	H_2O	198; 94·050	H_2O	198; 94·050
N	1117 × 0·245 = 273·665	N	1117; 273·665		
4N+O	1436 × 0·238 = 341·768				
CO_2	217 × 0·217 = 47·089	CO_2	217; 47·089	CO_2	217; 47·089
Total	2968 × 0·255 = 756·572		1532; 414·808		415; 141·139

If now the total number of units of heat, which resulted from the burning of 100 pounds of coal gas, be divided by the sum of weights of products of combustion, multiplied by their specific heat, the increment of heat to the products will be given by the result; which, added to the original or normal heat of the gas and air (here taken

at 70°), will give the absolute temperature of the products as they are assumed to exist in the three suppositions.

Supposed absolute temperature of flame of coal gas, where the products of combustion are taken to include the volume of air, which is the requisite for complete combustion:

$$= \frac{1945000}{756 \cdot 572} + 70° = 2641°.$$

Supposed absolute temperature of flame of coal gas, where the products of combustion are taken to include the air needed to supply oxygen of chemical combination:

$$= \frac{1945000}{418 \cdot 804} + 70° = 4760°.$$

Supposed absolute temperature of flame of coal gas, where only the oxygen of chemical combination is taken into the estimate:

$$= \frac{1945000}{141 \cdot 139} + 70° = 13885°.$$

At the same time we are discussing the absolute temperatures of coal gas flames, it may prove interesting to examine, separately, those of the three gases which compose it, as follows:

	Weight, pounds.	Oxygen, pounds.	Product of com.	Weight, pounds.	Specific heat.	Units heat.	Intens. of flame.
Hydrogen, H	1	8	H_2O	9	$\times$ 0·475 = 4·275)	52447(	12268° + 70° = 12338°
Carbon, C	1	2 2-3	CO_2	3 2-3	$\times$ 0·217 = 0·796)	14500(	18223° + 70° = 18293°
Carb. ox., CO	1	4-7	CO_2	1 4-7	$\times$ 0·217 = 0·341)	4329(	12694° + 70° = 12764°

The value for the heat effect of one pound of hydrogen is derived in the same way as was used in the estimate for coal gas, as follows:

Total heat effect of 1 lb. of hydrogen,	= 62,032	units.
Deduct latent heat of 9 lbs. vapor of 70°, 1065°, ...	= 9,585	"
Heat effect of 1 lb. of hydrogen, without condensation of vapor, .	= 52,447	"

These estimates of the heat of the flame of gases have taken for granted the constancy of the relative values of specific heats at high temperatures, and the results may therefore be considered as only approximations of the truth; still they give, probably, the most nearly correct estimate of the values of intensity possible.

The heat evolved by the burning of coal gas is dispersed in two ways—as radiant, and as convected or imparted heat. With the

open burner, it is fair to assume that a large portion of the heat is dispersed as radiant heat. According to Peclet, 50 per cent. of the heat of a flame of burning wood or coal is dispersed as radiant heat, and it does not seem to be an improper assumption, that one-half the heat of burning of coal gas will be dispersed as radiant heat, and the other will be communicated to the gases of combustion, and disseminated by convection and intermixture with the surrounding air. The limited base from which the flame of a gas burner emerges, as compared to the magnitude of the flame or burning surface, prevents the loss or expenditure of radiant heat upon the fuel (which would again impart its heat to air in contact before burning), and thus reduces the convected heat to its least quantity. The supposition appears the more reasonable when we consider the enormous intensity of the heat of chemical combination; nearly 14000°, as above indicated, when unmixed with other gases to absorb its heat. If we proceed on this supposition, it follows that the convected heat of 100 pounds of coal gas becomes one-half of 1945400 = 972700 units; and this heat imparted to the products of combustion, when they are taken to include the volume of air necessary to effect complete combustion, gives the temperature of these products:

$$= \frac{972500}{756{\cdot}572} + 70° = 1356°.$$

The relations of volumes of the products of combustion of coal gas to the weights as ascertained, can be seen by the following table—estimated at 70°:

Product.	Spec. grav.	Wt. per cu. ft.	Cubic ft. per pound.		Wt. of product.		Cu. ft. of product.	Cu. ft. per ft. of gas.	Vol. per ct. of product.
H_2O	0·622	0·0466	21·45	×	198	=	4247	1·355	10·45
N	0·972	0·0729	13·73	×	1117	=	15332	4·891	37·73
4N+O	1·000	0·0750	13·34	×	1436	=	·19158	6·111	47·15
CO_2	1·524	0·1142	8·754	×	217	=	1900	0·606	4·67
					2968	=	40637	12·963	100·00
Gas	0·426	0·0319	31·35	×	100	=	8135	1	7·71
Oxygen*	1·106	0·0829	12·07	×	319	=	3849	1·228	9·47
Air	1·000	0·0750	13·34	×	1432	=	19103	6·094	47·01
Dbl. Air	1·000	0·0750	13·34	×	2868	=	38259	12·204	94·15
Heat total, units			1945400					622	
Heat convected, units			972700					311	

[* The oxygen taken is that of actual combination, and represents the quantity needed, with coal gas, when used for the lime light or Bunsen burner.]

The preceding computation can be verified by another arrangement of data, in which volumes alone appear, taking the second column from the table of reduction of volumes to weight:

	100 vols. × spec. grav.	H.	C.	O.	N.	Result of combustion of hydrogen and carbon with definite proportion of oxyg.	
Hydrogen, H	3·114	3·114					
Marsh gas, CH_2	20·124	5·031	15·098				
Olefines, C_2H_4	7·848	1·121	6·727				
Carbonic oxide, CO	5·802		2·487	3·315			
Carbonic acid, CO_2	3·048		0·831	2·217			
Air, 4N+O	2·000			0·444	1·556		
Aqueous vapor, H_2O	0·622	0·069		0·536			
						H_2O	CO_2
100 vols. × spec. grav., totals	42·558	9·335	25·138	6·529	1·556		
Per cu. ft. gas, weights, lbs.	0·0319	0·0070	0·0188	0·0049	0·0012	0·063	0·069
" " volumes, cu. ft.	1·000	1·349		0·059	0·017	1·351	0·605

In general, the combustion of all substances, oils, fat acids, or gases used for illuminating purposes, is unquestionably perfect combustion of the carbon and hydrogen elements into carbonic acid and aqueous vapor. Neither smoke nor carbonic oxide, nor hydrogen in free or combined state, other than water, can be found in the air of any room where the lighting is at all satisfactory to the occupants, and the production of heat, as has been estimated, becomes one of the positive facts in physics beyond question as to existence and quantity. With the case of the open gas burner, it is possible that one-half the heat of the flame is dispersed as radiant heat, but this dispersal does not, however, get rid of the heat in a room; it merely transfers it to solid bodies of less temperature, more or less remote from the flame, which again are cooled in great measure by contact of the air of room, which takes up their excess of warmth, so that the heat emanating from a burner really is nearly all expended in the air. But when the burners are shaded by glass or other shades, and particularly for argand burners with chimneys, the larger part of the radiant heat is cut off by the shade or chimney, or both together, and imparted to an unknown volume of air which accompanies the air for or of combustion. As a practical application, it may be well to consider what volumes of air are requisite to disperse the heat of gas lights if the air in any part of a room is limited to some definite temperature.

The following table exhibits the effect of gas burning from a single burner of the usual sizes:

(All figures refer to quantities per hour—air of room and gas at 70°.)

Gas burned, cu. ft.,	1	3	3½	4	4½	5	6	8
Carbonic acid evolved, cu. ft.,	0·606	1·82	2·12	2·42	2·73	3·03	4·24	4·84
Aqueous vapor " " "	1·355	4·07	4·74	5·42	7·10	7·78	8·13	10·84
" " " lbs.,	0·063	0·19	0·221	0·253	0·285	0·317	0·38	0·506
Oxygen removed, cu. ft.,	1·228	3·68	4·30	4·91	5·52	6·14	7·37	8·60
Heat produced, units,	622	1866	2177	2488	2799	3110	3732	4976
Coal to produce equal heat, lbs.	0·062	0·19	0·22	0·25	0·28	0·31	0·37	0·50
Air supply = 10 cu. ft. per min. per cu. ft. gas } cu. ft.,	600	1800	2100	2400	2700	3000	3600	4800

With the supply of air to each gas burner given by the preceding table, the temperature of the current ascending from open burners, where one-half the heat is supposed to be radiated away, becomes 99°; while the temperature of the same current arising from an argand burner, where the glass chimney will have intercepted the radiant heat, becomes 128°.

The figures for this temperature are thus obtained: The weight of air at 70° is 0·075 pound per cubic foot, which, multiplied by 0·238, the specific heat of air, gives 0·01785 unit as the capacity of one cubic foot of air for each degree Fahr.; with 600 feet of air supply per hour to 1 foot of gas, the capacity of the 600 feet becomes 10·71 units for each degree of elevation of temperature; and to absorb 622 units by the 600 cubic feet of air, the latter will become heated

$$\frac{622}{10{\cdot}71} = 58°,$$

which, added to the 70° of primary temperature, give 128° as the final one when all the heat is taken up by the air. When but half the heat is assumed to be given to the air, we have 29° + 70° = 99°.

The computation of the temperature to accompany any other volume of air supply is easy. Thus, if for each cubic foot of gas burned per hour—normal temperature 70°:

Air supply per minute, cu. ft.,	5	10	15	20	25	30
Corresponding air supply per hour, cu. f.,	300	600	900	1200	1500	1800
Temperature of air ascending from open burners,	128°	99°	89°	84½°	81½°	79½°
Temperature of air ascending from argand burners,	187°	128°	118°	99°	93°	89°

The estimate of weight of coal, the consumption of which will produce an equal effect in warming a room with gas burning, is not based

on the theoretical value of coal as a producer of heat, but upon average usual results from heating apparatus, as steam or hot water apparatus, hot air furnaces of best construction, or close stoves, in utilizing the heat of the fuel. That is, 10,000 units of heat have been assumed to be given out efficiently by the consumption of one pound of good anthracite coal.

The capacity of the air requisite for dispersal of the heat of a gas flame, to take up the moisture generated by the process of burning, can be investigated. According to the best authority (Regnault, from Guyot's tables), saturated air has the following quantities of moisture per cubic foot of air:

Temperature of air,	70°	75°	80°	85°	90°	95°	100°	105°
Weight of moisture, lbs.,	0·0011	0·0013	0·0016	0·0018	0·0021	0·0024	0·0028	0·0032

If it is assumed that the air of supply is 70°, and has 60 per cent. of saturation, then such air has 0·0007 pound of water to each cubic foot, whence the capacity of this air, to take up moisture in becoming saturated, is:

0·0004	0·0006	0·0009	0·0011	0·0014	0·0017	0·0021	0·0025

and there will be needed to carry off the 0·063 lb. of moisture which the burning of each cubic foot of gas per hour evolves:

Air at given temperatures, cu. ft.,	158	105	70	57	45	37	30	25

Comparison of these quantities, with the volume of air supply, and corresponding resulting temperatures as given in the previous table, demonstrates that the moisture generated by gas burning will be absorbed, in all cases, into the air for dispersal of heat.

While it appears to be impossible to discern any error in the method and data of this inquiry, and the mathematical accuracy (errors of computation excepted) of the results seems to be unquestionable, yet their application to practice is found to need great qualification. The material products of combustion, *i. e.*, aqueous vapor and carbonic acid, and the corresponding abstraction of oxygen from the air of a room, are established facts, but it is very difficult to account for the dispersion of the heat. Great allowance is needful for conductivity of the enclosing surfaces—floors, walls, ceilings, windows and doors—and also for fresh air currents, surreptitious or otherwise, before the heat imparted to the air, as derived from these computations, will conform to what is really found to be the heat effect

of gas lighting. For instance, a 4 ft. gas burner would be held to be ample for lighting a small bed-room, and such a burner is frequently permitted to remain burning all night in a room of, not to exceed, 800 cubic feet capacity. This burner, by the computation, would produce 2488 units of heat each hour. In moderate weather no considerable loss of heat from the surfaces enclosing the room is supposable, and the figures give 7200 cubic feet of air per hour (or 120 feet per minute) as the indispensable necessity to keep down the temperature to 19° above the normal one. To be sure, the current of gases ascending from the burner will reach the ceiling of the room at a greatly elevated temperature, perhaps 140° even, and a stratum of hot air next the ceiling be formed (unless some arrangement of ventilation removes the hot air at once), and then the conductivity of the ceiling will be brought into action, but yet it is hard to feel satisfied that this means is sufficient to account for all the loss of heat apparently demanded.

It must be admitted that further inquiry and experiment are wanted to elucidate the subject of the dispersal of heat of gas lights, and perhaps to review the entire subject of the quantity of heat produced by them.

THE OIL SANDS OF PENNSYLVANIA.[1]

By CHAS. A. ASHBURNER, M. S., Asst. Second Geological Survey of Pennsylvania.

The recent discussion among the producers, shippers and refiners of the petroleum of Pennsylvania, as to the advisability of the State Legislature passing a free pipe line law, which will permit the laying of pipes for the running of the crude material from the producing regions to the seaboard, has brought many points of interest, connected with one of the greatest industries of our State, before unnoticed, to the attention of the public.

One of the most important questions to the petroleum miner, and one which even the more enlightened of our oil men can answer only

[1] Paper read before the Engineers' Club of Philadelphia, Feb. 16th, 1878.

in a very vague and uncertain way, is, where is petroleum found? The question is an exceedingly broad one, and involves many considerations which cannot reasonably be noticed within the limits of a brief paper. The origin of petroleum, its connection with the sand in which it is found, the influence of the character of the oil sands on their productiveness, the relation of the surface rocks to the oil sands, and the bearing of surface indications upon the position of underlying oil belts, the connection between petroleum and natural gas, etc., are all vital questions which must be met before we can say where petroleum is found and where we may locate profitable wells.

I do not wish to anticipate any of the conclusions which our present Geological Survey may advance, to meet any or all of these questions which suggest themselves so pertinently to those interested in the petroleum industry, or express any views on the more important and practical question as to the position of producing territory, and the location of profitable wells. I have thought it would be of interest to the members of the Engineers' Club to give, in a general way, a vertical section of the rock formations, showing the relative position of all the oil horizons of Western Pennsylvania, together with an estimate of the daily production of each horizon.

That portion of the State in which petroleum has been found, lies entirely west of a line drawn across the State, from the State line at the southeastern corner of Greene County to the State line at the northeastern corner of McKean County.

For convenience of description, the oil regions may be divided into three groups or districts—the southwestern, the western and the northern.

The southwestern district may be said to include that part of the state south of the Ohio River, and west of the Monongahela River; the western, better known among the producers as the "lower country," lies in the water-basin of the Alleghany River, between Pittsburg, on the south, and the Philadelphia and Erie Railroad, on the north; and the third or northern district lies entirely north of the Philadelphia and Erie Railroad, in the counties of Warren and McKean, and extends ten miles into the State of New York.

The strata of Western Pennsylvania lie comparatively horizontal. The average dip of the rock from Bradford, near the State line, to Pittsburg, is about 18 ft. to the mile; that is, a rock which occurs at

water level at Bradford, at an elevation of 1450 ft. above ocean level, would be found at Pittsburg about 750 ft. below the same datum, or 1500 ft. below water level. Three thousand feet of the stratified rocks of the Carboniferous and Devonian Ages in Pennsylvania, have been found to contain petroleum. The highest stratum in which oil is found, occurs in the coal measures, 165 ft. below the Pittsburg coal seam, in Greene County; while the lowest occurs about 3200 ft. below the geological position of the Pittsburg coal seam in McKean County.

If we should drill a well in Greene County 3200 ft. deep, starting on the Pittsburg coal, we would pass through the horizon of all the sands and sandstones in which the petroleum of our State has been found.

This estimate is made on the assumption, that if the coal measures up to the Pittsburg seam should be restored in McKean County, the lowest oil-bearing rock in the northern district would be found the same depth below the Pittsburg coal, as the geological horizon of the same sand would be found below the same coal-bed in Greene County.

From observations in the western part of the State, we know that the rocks are subject to very marked and rapid changes in their thicknesses, in comparatively short distances. What the change in rock thickness may prove to be, between McKean and Greene Counties, we have not sufficient facts at hand to assert. Whether the total thickness of the stratified rocks between the Pittsburg coal and the "Sartwell" or lowest oil horizon, at localities between the two counties, shall be found to be a variable quantity, or much greater or much less than the above estimate, the fact, in itself, will not defeat the object of this paper, which is intended to point out the relative, and not the absolute, position of the oil sands one to another.

The petroleum, in the southwestern district, comes from the highest rocks; that in the northern, comes from the lowest; while the producing sands of the western district are found intermediate between the other two groups of rocks.

The southwestern district "oil-sand group" is about 800 feet thick, and is composed of three sandstone members, separated by intervals containing coal seams, slate and shale. The following is a general section of the group, by Prof. Stevenson:

1. Morgantown Sandstone, Dunkard Creek; thickness, 66 ft.
Lower Barren Coal Measures, shales and slates; thickness, 194 ft.

2. Mahoning Sandstone, Dunkard, Whiteley and Dunlap's Creeks; thickness, 50 ft.
Lower Productive Coal Measures; thickness, 85 ft.

3. Piedmont Sandstone and Coal Conglomerate, Dunkard Creek; thickness, 400 ft.

The first or upper oil sandstone shows considerable variation, and is oftentimes replaced by shale. It is a noticeable fact that in this case the shale contains no oil.

The Mahoning or second sandstone is quite constant in thickness, and is the principal repository of petroleum in the southwestern district. It frequently contains conglomerate layers.

The third or lower sandstone is made up of three members, an upper and lower sandstone member, separated by about 30 to 40 ft. of shale and coal. The upper member is regarded as the oil-bearing rock. The lower member, or Piedmont Sandstone, is the representative of the coal conglomerate or millstone grit.

Some of the characteristics of this district are quite different from those of the western or northern districts. In drilling, small crevices in the oil sands are of frequent occurrence; and it is a striking fact that the oil is said never to have been found except where a crevice was struck. The producers in this field have considered this fact necessary to the original production of oil itself.

According to Prof. Stevenson, the oil in nowise owes its origin to disturbance of strata, and the only effect of the disturbance has been to provide reservoirs for the oil in the rock already oil-bearing.

Between the bottom of the coal conglomerate, which is the lowest member of the lowest oil-producing sandstone of the southwestern district, and the "first oil sand," which is the highest producing sandstone of the western district, there is an interval of from 650 to 700 ft. of shales and sandstones, forming the Barren Oil Measures, or Mountain Sand group. These rocks are perfectly barren of any economical strata; they contain no coal, iron or oil. In Butler County this group often contains gas.

The Greene County "oil sand group," and the upper part of the Barren Oil Measures, belong to the Carboniferous Age, while

the oil sands of the western and northern districts are Devonian rocks.

The following is a general section of the oil sands of the western district:

First sand, ...	40 ft. thick.
Interval, ...	105 ft.
Second sand, ...	25 ft. thick.
Interval, ...	110 ft.
Third sand, ...	35 ft. thick.
Total thickness of the group, . .	315 ft.

All the oil from Clarion, Butler and Venango Counties, which comprise our most productive field, comes from this group, and from one of the representatives of the three sands. These sands are sometimes split up into several members, giving rise to what are known as the "fourth," "fifth," and "sixth" sands of Oil Creek.

The first sand produces a heavy lubricating oil from 30° to 35° gravity; the second, an oil of about 40° gravity; and the third sand, the usual light oil, from 45° to 50° gravity.

The third sand of this district is the most productive, and supplies most of the oil of commerce. According to Mr. Carll, assistant in the Oil Regions, "the well records along the 'green oil belt' in Venango County, show a great uniformity in the arrangement of the sand rocks. They are sharply defined, massive, and lie at regular intervals. Going southeast from this belt, they gradually split into several members, fine down in their composition, and shade away into shales. Going to the northwest, the third sand terminates rather abruptly—the second sand overlaps it, and continues a mile or two farther; the first sand overlaps the second, and extends, in some places, a long distance beyond. The majority of the wells producing from the first and second sands, are located along these overlapping edges of the sand rocks.

"Wherever the third or lowest sand is adapted to the production of oil, the main deposit is found in it, and not in the sands above. The first and second sands, although of good quality, do not produce oil along the centre of the belt. In some wells, it is true, oil has

been obtained from all three of the sands. These wells are not on the axis, but near the edge of the third sand; and but a short distance further from the centre, no third sand can be found."

These are very suggestive facts, and seem to point to the conclusion that the oil sands are merely reservoirs, which have acted as sponges in absorbing the oil which has ascended from a much greater depth. The oil in this case would not be indigenous to the rock in which it is found.

If indigenous, why is the bulk of the "first sand oil" found in the edges of the first sand which overlap or extend beyond the edges of the second and third sands? The same question suggests itself in regard to the most productive portions of the second sand.

Between the "third oil sand" of the western district and the Warren sand of the northern district, there is an interval of about 600 ft. of shale, which is entirely barren. The Warren oil sand is very irregular in character, and the oil is found at horizons varying from 600 to 800 ft. below the Venango third sand.

The oil obtained from the Warren horizon resembles very much the "third sand oil."

Among many of the producers the oil is known as "slush oil," on account of the irregular and poor quality of the sand, and the rapid diminution in the production of the wells, which are large producers when first struck.

The productive horizon of the Bradford oil belt in McKean County and Cattaraugus County, New York, occurs probably 300 ft., more or less, below the Warren horizon. The sand in the Bradford belt is finer and closer in texture than that of any other producing belt in Pennsylvania; it is also more constant in character over a wide area. These facts have much to do with the small percentage of risk which the producer experiences in obtaining "dry holes," or non-producing wells. The Bradford belt is the surest and safest territory in which to operate.

Of the wells completed in November in the Butler, Parker and Clarion districts, 14·8 per cent. were "dry holes;" while in the Bradford district only 6·6 per cent. were "dry holes." This is more than the usual monthly average of "dry holes" in Bradford, on account of the great number of "wild cat" or test wells which were drilled.

The oil is of about the same gravity as the "third sand oil," but somewhat different in character. On account of the difference in the sand and in the oil, the Bradford wells are never pumped continuously, but "by heads," or at regular intervals. This is found necessary, in order to keep the sand open and porous. When the interstices of the sand become "choked" by the heavier parts of the oil, the sand is broken up and loosened by nitro-glycerine torpedoes, which are lowered to the depth of the producing sand and exploded.

A great deal of the oil obtained from the Bradford belt, along the State line, is found several hundred feet above the regular producing sand. The horizon of this oil may prove to be the same as the horizon of the Warren oil.

The lowest oil found in the northern district, and, in fact, in Pennsylvania, comes from what I have called the "Sartwell oil sand," which has but recently been discovered in Liberty Township, McKean County. This horizon is, probably, 400 ft. below the Bradford sand; it has not as yet been thoroughly tested; at present it is non-productive.

Petroleum has never been found in the three groups of oil measures in the same locality. As the oil sands of the southwestern and western district outcrop, or come to the surface, in the northern district, we may never expect to find oil in them north of the Philadelphia and Erie Railroad. The question as to whether we will ever find the northern district oil in the western district, and the oil of both of these districts in the southwestern district, is a very suggestive one. If our future explorations shall prove such to be the case, we are safe in the assertion that, at the present price of crude oil, the wells would be too deep and too expensive to warrant the development.

Production.

I am unable to state how much petroleum is produced in the southwestern district. Quite extensive developments were made in Greene County last fall, and I am informed, on good authority, that one of the new wells was producing 50 barrels a day. No oil territory has yet been found in Washington County.

The following table shows the production in the western district, in November last:

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Name of Districts.	No. of bbls. of oil produced in the month.	Average per day for the month of 30 days.	No. of wells producing.	No. of wells drilling.	No. of wells completed in November.	Aggregate daily production of new wells.	Daily Average of new wells.	No. of Rigs building.	Dry holes in Nov.
Butler, Parker, Clarion,	709170	23639	4470	275	209	2617	12½	159	31
Scrubgrass,	120000	4000	275	10	12	162	13½	9	2
Franklin,	12000	400	370	10	6	42	7	7	2
Reno,	3000	100	31	......	......	....	......	......	.....
Oil City,	24000	800	365	10	5	32	6½	8	2
Rouseville,	12000	400	200	3	3	21	7	2	1
Rynd Farm,	12000	400	125	2	2	14	7	2	.....
Columbia,	3750	125	31	......	......	....	......	......	.....
Petroleum Cr.	3000	100	50	1	2	10	5	1	1
Shamburg,	6000	200	96	1	2	12	6	1	.....
Titusville,	45000	1500	768	10	10	80	8	9	3
Pithole,	6000	200	78	2	2	6	3	2	1
Fagundas,	6000	200	150	1	4	16	4	1	2
Tidioute,	12000	400	83	5	6	42	7	4	2
Beaver,	7500	250	144	12	4	20	5	3	1
Totals,	981420	32714	7236	342	267	....	......	208	48

The following is the production, for the same month, in the northern district:

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
Warren,	12000	400	122	5	4	28	7	3	1
Bradford,	180000	6000	965	218	120	1200	10	152	8
Totals,	192000	6400	1087	223	124	....	......	155	9

The total daily production for November, in the western and northern districts, was 39,114 barrels; in the month of October the same districts produced 40,946 barrels per day. This does not

necessarily show a decrease in the actual production; it is probably an error in the estimates.

The above figures were taken from the *Petroleum Reporter*. From reports made to me during the past week, the Warren district is said to be producing nearly 500 barrels, while the Bradford daily production approaches 8500 barrels. Of the Bradford production, about four-fifths come from the regular Bradford sand, and one-fifth from the higher horizons in the "slush oil" wells.

CRANK PINS AND JOURNALS.[1]

By WILLIAM D. MARKS, Whitney Professor of Dynamical Engineering, University of Pennsylvania.

(15) THE CRANK PIN.—The crank pin has ever been one of the most troublesome parts of the steam engine to the mechanical engineer. The mere determination of its proportions, so that it will not break under the strain put upon it by the pressure of the steam upon the piston head, does not suffice, and often results in trouble from heating when the engine is at work. It therefore becomes a first consideration to so proportion crank pins as to prevent heating, their strength being a matter of secondary importance to be afterwards investigated, if it is deemed necessary to do it.

Before taking up the mathematical part of our consideration, it will be of practical value to quote, from the writings of General Morin, the following remarks:

"But it is proper to observe, that from the form itself of the rubbing body (cylindrical), the pressure is exerted upon a less extent of surface, according to the smallness of the diameter of the journal, and that unguents are more easily expelled with small than with large journals. This circumstance has a great influence upon the intensity of friction, and upon the value of its ratio to the pressure.

"The motion of rotation tends of itself to expel certain unguents, and to bring the surfaces to a simply unctuous state. The old mode of greasing, still used in many cases, consisted simply in turning on

[1] An extract from a course of lectures on "The Relative Proportions of the Steam Engine."

the oil, or spreading the lard or tallow upon the surface of the rubbing, and in renewing the operation several times in a day.

"We may thus, with care, prevent the rapid wear of journals and their boxes; but with an imperfect renewal of the unguent, the friction may attain ·07, ·08, or even ·10 of the pressure.

"If, on the other hand, we use contrivances which renew the unguent, without cessation, in sufficient quantities, the rubbing surfaces are maintained in a perfect and constant state of lubrication, and the friction falls as low as ·05 or ·03 of the pressure, and probably still lower.

"The polished surfaces, operated in these favorable conditions, became more and more perfect, and it is not surprising that the friction should fall far below the limits above indicated." (Bennett's Morin, pp. 307–8.

If the unguents are expelled by extreme pressure, so that the surfaces are simply unctuous, the friction increases rapidly, and the surfaces begin to heat and wear immediately.

These statements apply with equal force to cast iron and cast iron; cast iron and wrought iron; cast iron and brass or Babbitt's metal; or with steel or wrought iron in the place of cast iron.

The supposed superiority of brass or Babbitt's metal lined boxes over iron boxes, in positions very liable to heating, lies in their greater softness and conductivity for heat. Brass will conduct heat away from two to four times as rapidly as iron. However, the film of unguent interposed may render the conductivity of brass of less avail than is generally supposed, and the advantage lies only in the fact that being a softer metal, in case of heating, the surface of the softer metal receives the principal damage.

It is, perhaps, good practice to use brass or soft metal wherever the pressure exceeds 125 lbs. per square inch of projected area. At lower pressures an ordinary good lubricating oil may be relied upon to form a film, and run without breaking at ordinary speeds. (Winter strained lard oil was the lubricant used, diameter of journal 3 inches, making 120 revolutions per minute. But a few experiments were made. The continuity of the film of lubricant is affected by so many different conditions, that it is impossible to fix any exact limit of pressure.)

With soft metal or brass bearings, good results can be obtained at pressures of 1000 lbs. or more per square inch of projected area; if,

however, the film of unguent does break at these higher pressures, heating begins almost instantly, and if the surfaces in contact are both of hard metal, as iron and iron, injury to both at once results, while if the boxes are brass or some of the softer metals, the continuity of the surface film may be restored by increased lubrication, or by stopping and cooling as soon as heating is observed.

Several expedients are used to keep bearings, which have a tendency to heat, cool.

The introduction of rotten stone, or sulphur with oil, is perhaps the best. Quicksilver, or lead-filings, introduced with oil, coat the rubbing surfaces, and diminish the heating where the rubbing surfaces are very much scored.

A great increase of the velocity of the rubbing surfaces renders bearings more liable to heat than a great increase in pressure, although the total amount of work done by friction is the same in both cases, and is probably accounted for by the more rapid expulsion of the lubricant.

As the cause of the heating of bearings, when they are of tolerably good workmanship, is the transformation of the work of friction into heat, we see that it is necessary to reduce the friction, as much as possible, by the perfect smoothness of surfaces in contact, the interposition of lubricants, and the reduction of the speed and pressure upon the rubbing surfaces.

In all machines there is a limit, below which we cannot reduce the speed and pressure of the rubbing surfaces, and we must, therefore, so proportion journal bearings as to cause no more work due to friction, *i. e.* heat, to be produced than can be conveyed away by the unguents, the atmosphere, and the conductivity of the metals, without raising the temperature of the bearing appreciably.

From the statistics of the working of the crank pins of four screw propellers in the United States Navy (Van Buren, "Strength of Iron Parts of Steam Machinery," page 24), we take the following statement and table:

"The crank pins of these vessels worked cool, giving but little trouble, which is the exception rather than the rule for screw engines."

The projected area of crank pin journal, given in column 7, is that rectangular area formed by a central section of the crank pin journal, in the direction of its length.

Columns 1, 2, 4, 5, and 6, are given. Columns 3, 7, 8, 9, 10, and 11, are calculated from them.

In calculating column 9 from columns 3 and 8, we have assumed the coefficient of friction at ·05, which is the highest value given by Gen'l Morin for constant lubrication, and the most probable in the present cases.

Column 11 is derived from columns 3 and 7. Column 10 is derived from columns 7 and 9.

Name of Vessel.	1. Diameter of steam cyl.	2. Pressure per sq. inch.	3. Total force of steam pressure on piston head.	4. No. of strokes per minute.	5. Length of crank pin.	6. Diameter of crank pin.	7. Projected area of crank pin.	8. Velocity of rubbing surfaces, in feet, per minute.	9. Total work of friction in foot pounds per minute.	10. Work of friction per sq. inch of projected area in foot-pounds per minute.	11. Pressure per sq. inch of projected area.
	in.	lbs.	lbs.		in.	in.	sq. in.				
Swatara..........	36	40	40716	160	12	8·5	102·	178·	362372	3552·6	399·5
Saco..............	30	40	28274	180	9	7·5	67·5	176·7	249801	3700·7	419·
Wampanoag.....	100	40	314160	62	27	16·	432·	129·8	2038898	4719·7	727·2
Wabash..........	72	28	114002	100	16	15·	240·	196·3	1118910	4662·1	475·
Averages										4159·	505·

From column 10 of the table, we find the average amount of work per square inch of projected area of crank pin journal, which, in the cases cited, has been borne without heating, to be 4159 ft. lbs. per minute, and in making use of this quantity in our subsequent calculations, we are on the safe side, if the coefficient of friction (assumed at ·05) has not been taken too small.

Let $d=$ the diameter of the piston head in inches.

Let $P=$ the mean pressure in the steam cylinder in pounds per square inch.

Then, 7854 $d^2P=$ the mean pressure on the piston head in pounds.

Let $f=$ the coefficient of friction.

Let $l_3=$ the length of the crank pin journal in inches.

Let $d_3=$ the diameter of the crank pin journal in inches.

The mean *force* of friction at the rubbing surfaces of any crank pin journal, per square inch of projected area, is

$$= \cdot 7854\, f\, \frac{P d^2}{l_3 d_3}.$$

Let N = the number of strokes per minute (= twice the number of revolutions).

Let w = the work of friction per minute.

The space passed over by the force due to friction, in one minute,

$$= \frac{\pi}{2} N d_3 = 1 \cdot 5708\, N d_3 \text{ inches,}$$

and we have for the work of friction, *i. e.*, heat, per minute,

$$w = 1 \cdot 5708 \times \cdot 7854 f \frac{P N d^2}{l_3} \text{ inch lbs.}$$

From this formula the diameter of the crank pin journal (d_3) has vanished. Why it has vanished will be understood when we observe that the force per square inch of projected area, due to friction, is inversely as the diameter of the journal; while the space passed over by this force is directly as its diameter.

Replacing w in the last formula by the mean value derived from column 10 of the table, = 4159 ft. lbs. = 49908 inch lbs., we have

$$49908 = 1 \cdot 2337\, f \frac{P N d^2}{l_3}.$$

Therefore, $l_3 = \cdot 0000247\, f\, P\, N\, d^2$, ... (20).

Considering formula (20), we see that the length of the crank pin increases and decreases with the coefficient of friction, the mean steam pressure per square inch, the number of strokes per minute, and with the square of the diameter of the steam cylinder.

A consideration of the component formulæ of (20), shows that as the crank pin journal decreases in size, the pressure per square inch becomes greater; but if this reduction in size is obtained by a diminution of the diameter (d_3) of the crank pin journal, the work per square inch of projected area is not increased, for the velocity of the rubbing surfaces, by this means, is decreased in the same ratio as the pressure is increased.

Within reasonable limits, as to pressure and speed of rubbing surfaces, the general statement may be made:

The longer any bearing, which has a given number of revolutions and a given pressure to sustain, is made, the cooler it will work, and its diameter has no effect upon its heating.

Example:

Let $d = 30''$, $N = 180$, and $P = 40$ lbs. per square inch.

We have, by substitution in formula (20),

$$l_3 = \cdot 0000247 \times f \times 40 \times 180 \times 900 = 160 \cdot f.$$

If in this we take $f = \cdot 03$ to $\cdot 05$ for perfect lubrication, we have

$$l_3 = 4 \cdot 8'' \text{ to } 8''.$$

If we take $f = \cdot 08$ to $\cdot 10$ for imperfect lubrication, we have

$$l_3 = 12 \cdot 8'' \text{ to } 16''.$$

The results show the great advantages arising from constant oiling of bearings.

As a practical application under the most trying conditions, we find that Messrs. Wm. Sellers & Co. are able to double the speed of their bolt cutters when an oil pump is used, without injury to the dies.

NOTE.—If for locomotive crank pin journals we assume N the number of strokes per minute $= 600$.

P the pressure per square inch in lbs. $= 150$, the formula (20) being changed to

$$l_3 = \cdot 00000247\, f\, P\, N\, d^2,$$

by removing the decimal point one place to the left, will give the length of journal commonly assumed in successful practice, if we assume the coefficient of friction at $\cdot 06$.

The above formula then becomes

$$l_3 = \cdot 013\, d^2.$$

This formula would show the amount of heat per square inch of projected area conveyed away from the crank pins of locomotives to be ten times greater than in the case of marine engines, did not the variations of speed and frequent stoppages of a locomotive prevent comparison.

Example:

Let $d = 18$ inches.

We have,

$$l_3 = \cdot 013 \times 324 = 4 \cdot 21 \text{ inches.}$$

We will next take up the diameter of the crank pin journal.

It is necessary, first, to determine its length by formula (20), and with this length to determine the proper diameter.

Let $a =$ the deflection of pin under stress in inches.
Let $S =$ the stress on pin in lbs.
Let $E =$ the modulus of elasticity of wrought iron $= 28000000$ lbs.
Let $W =$ the measure of the moment of flexure of the pin.
Let $l_3 =$ the length of journal in inches.

The deflection of a beam fixed at one end, and loaded at the other ("Weisbach's Mechs. of Eng.," Sec. IV, Art. 217), is

$$a = \frac{S\,l^3}{3\,W\,E}$$

If, again, the beam be supposed to be uniformly loaded and fixed at one end, its deflection will be (W. M. E., Sec. IV, Art. 223)

$$a_2 = \tfrac{1}{8}\,\frac{S\,l^3}{W\,E},$$

and if for the load at the end we concede a deflection of $\frac{1}{100}$ of an inch, we have for the same load under the two cases above mentioned,

$a_1 = \cdot 01$ inch,
$a_2 = \cdot 0038$ inch.

Then taking the most unfavorable case, *i. e.*, the load at the end, we have,

Letting $S = \dfrac{\pi\,d^2}{4}\,P_b$,

Letting $P_b =$ the greatest pressure of steam in cylinder $=$ the boiler pressure,

Letting $W = \dfrac{\pi\,d_3^{\,4}}{64}$,

$$\tfrac{1}{100} = \tfrac{1}{3}\,\frac{\dfrac{\pi\,d^2}{4}\,P_b\,l_3^{\,3}}{\dfrac{\pi\,d_3^{\,4}}{64}\,28000000} = \frac{16\,P_b\,l_3^{\,3}\,d^2}{84000000\,d_3^{\,4}}$$

$$d_3^{\,4} = \frac{1600}{84000000}\,P_b\,l_3^{\,3}\,d^2 \quad . \quad . \quad . \quad . \quad . \quad . \qquad (21).$$

$$d_3 = \cdot 066\,\sqrt[4]{P_b\,l_3^{\,3}\,d^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad , \qquad (22).$$

Example:

Let $P_b = 60$ lbs. per square inch.

Let $l_3 = 8$ inches.

Let $d = 30$ inches.

Substituting in formula (22) we have

$$d_3 = \cdot 066 \sqrt[4]{60 \times 512 \times 900} = 4 \cdot 79 \text{ inches.}$$

There is no need of an investigation of the strength of a crank pin, as the condition of rigidity gives a great excess of strength.

The length of a steel crank pin is just the same as that of a wrought iron pin, and the modulus of elasticity of steel is so nearly equal to that of wrought iron, as to make formula (22) serviceable for both steel and wrought iron alike.

Referring to the table, we find the average pressure per square inch of projected area to be about 500 lbs.

If now we divide the whole pressure upon the crank pin by 500, we obtain the projected area required when this limit is not to be exceeded.

The equation $d_3\, l_3 = \dfrac{\pi\, d^2 P}{4 \times 500}$ gives $d_3 = \cdot 00157 \dfrac{d^2 P}{l_3}$.

Example:

Let $P = 40$ lbs., $l_3 = 8''$, $d = 30''$,

$$d_3 = \cdot 00157 \frac{900 \times 40}{8} = 7 \cdot 06 \text{ inches.}$$

This latter method is perhaps the most practical, and has the advantage of limiting the pressure. It will almost always give larger results than the preceding method.

For journals in general,

Let R = force on bearing in pounds.

Let l = length of bearing in inches.

Let d = diameter of bearing in inches.

Let T = the number of turns per minute.

Let f = the coefficient of friction.

And we have

$$49908 = \pi\, T d \cdot f \frac{R}{l\, d},$$

$$l = \frac{\pi}{49908} f\, T R = \cdot 000063 f\, T R,$$

giving the minimum length of bearing allowable, which should always be exceeded where circumstances will permit.

WATER SUPPLY OF THE STATE OF NEW JERSEY.

Report by the Committee on Water Supply, read at Meeting of N. J. State Sanitary Association, held at Princeton, Oct. 17th, 1877.

By ALBERT R. LEEDS, Chairman.

[Continued from Vol. lxxv, page 199.]

An important subject of inquiry in relation to the causes which may affect the taste and the wholesomeness of drinking-waters, was brought into prominence, by the excessive mortality, during the early part of June of this year, among the fish in the Passaic. Numerous articles, calculated to alarm the inhabitants of towns using Passaic water, were published by the local press, and also in New York. It was stated that thousands of fish had fallen victims to disease of an epidemic character, and the number of those perishing would suffice to contaminate the water; while the probability was that the same agencies which made the water fatal to fish, would render it detrimental to human beings. Many explanatory theories were advanced, such as the washing into the rivers of Paris green, used to arrest the ravages of the Colorado beetle. Some attributed it to the use of arsenical or other poisonous dye-stuffs, by establishments at Paterson, or the introduction of unusual amounts of manufacturing refuse, waste acids, alkalies, or other chemicals. The latter was the favorite theory, and received support from persons who had presumably examined somewhat into the matter.

I made two visits to Paterson, during the progress of the epidemic, and spent several days in collecting information. Both banks of the river, as far down as the Dundee dam, and up to Little Falls, were examined. Unfortunately, the height of the epidemic had passed when newspaper attention was attracted, and circumstances had intervened which apparently had removed the exciting causes. I saw, however, sufficient dead fish, in advanced stage of decomposition, to render it probable that the mortality might not extravagantly be estimated by thousands. No naturalist appears to have critically examined into the nature of the fish-disease.

Valuable information, however, is contained in the following letter, in reply to certain inquiries addressed to him, from Mr. John C. Roe, Fish-Warden at Paterson: "The epidemic in the Passaic River

began about May 26th, 1877, and ended June 14th. In the year preceding, there was no noteworthy exhibition of disease, but in 1875, it prevailed about one month later, in a much milder form than in 1877. Previous to this, nothing of importance had come to my notice, except an occasional dead sucker or mullet. These are to be found in almost any of our waters during the months of July and August, and are killed by what we term a blood-sucker, which attaches itself to the caudal fin. The epidemic this year was traced as far as Hanover, and to Peckman and Pequannock Rivers, which are head-waters of the Passaic. I visited Budd's Lake in Morris Co., and also Hopatcong and Stanhope reservoirs, and found the same disease, only in a very mild form.

"The species of fish affected, named in the order of their mortality, are as follows:—Sucker, mullet, chub, roach, sun-fish, yellow perch, cat-fish, and a few pickerel. In almost every case, diseased fish were found in the stomachs of the yellow perch and pickerel, and had probably caused their death.

"The disease appeared to attack the back-bone of the fish just below the head, and extend to the tail, the flesh decaying along the bone. In its last stages, red blotches or spots appeared on the fish, and were quickly followed by death. According to my observations, death ensued about 5 days after the fish were attacked. In the places where the disease most prevailed, the water varied in depth from 3 to 8 feet. The water was unusually low during the epidemic, in fact, lower than I ever recollect it to have been at that season of the year, and the mercury generally stood at 90° during the day, and from 65° to 80° during the night. My opinion is that the extremely warm weather, and the extremely low condition of the river at that season, caused a rapid growth of vegetable life, and the purging of the water, brought about by the above extremes, caused the vegetable matter to decay and produce a poison.

"The New York papers, the *Herald*, *Tribune*, and *Sun*, have each claimed to have discovered the cause. The *Tribune* finds it in the refuse matter coming from the factories in Paterson and vicinity, and asserts that the fish infected with the disease move up stream to get to pure water. I should like to know how they got over Passaic Falls, also the dam above the Falls, also Beatties' dam at Little Falls, 4 miles above Paterson. The *Herald* attributes the disease to the same cause, but goes only as far as Passaic City, 4 miles below Paterson.

The *Sun* claims that the locusts, which appeared in large quantities, were eaten by the fish, which were poisoned by them. But it is a well-known fact, that where the locusts were the most plentiful, no traces of the epidemic could be found. The fish affected, moreover, were not fish that feed on locusts, but fish that feed entirely from the bottom. I experimented with fish in the first stages of the disease, by giving them a bath of strong salt water, and then placing them in pure water. I found that a number recovered. I have also noticed a great many fish that have only one eye, and occasionally find one that appears as black as tar. I think they are fish that have recovered. My belief during the epidemic was that the first rain sufficient to raise the water 6 inches, would purify the atmosphere and water, and terminate the trouble. After the first rain no traces of the epidemic could be found. The sex of fish destroyed was about five female to one male. I have examined a number of fish taken from Croton reservoir this season, and found, in most every case, death was caused by blood-suckers."

The physical circumstances, important to note, are: that, prior to the epidemic, there had been a period of exceeding drought; less water, I was informed by Mr. Fowler, the President of the Society for the Promotion of Useful Manufactures, going over the dam at Paterson, than ever before at the same season. The heat, moreover, both in intensity and in duration, had been excessive and unusual. These circumstances appear to have combined, to increase the operation of agencies inimical to the fish-life in streams, which in all years operate to a certain extent, but seldom to produce an alarming mortality. The low water and warm weather, noticeable at these times, were accompanied by the appearance of unusual amounts of aquatic plants of a low order of vegetable life. From these circumstances, it appears that the following hypotheses are reasonable:

1. That the rapid development of vegetable growth may be attended with the production of vegetable organisms, which act as specific poisons upon fish-life.

2. That their decay, assisted by the intense heat of the sun falling upon areas covered by slight depth of water, results in a disintegration, by which they are diffused through the water, and, by means of the gases evolved by their decomposition, are floated to the surface. The organic impurities of a vegetable origin thus suspended in, or dissolved by, the water, may possibly be sufficient to originate disease.

3. The supply of dissolved oxygen may, by the operation of these causes, be lowered to such a point that it becomes incapable of supporting life among certain species of fish. In the first place, the oxidation of impurities and finely divided vegetable and animal matter, requires a large amount of oxygen. The covering of the river surface by floating algæ, would retard that aeration which is always taking place at the surface of a flowing stream. The stream would not be in receipt of that highly aerated water which flows into it from brooks and tributaries, descending from higher levels, or of air brought down by rain. Along with this exhaustion of oxygen, there would be a corresponding increase in the amount of dissolved carbonic acid, and of marsh gas, or even oily homologues of the marsh gas series, generated by the decay, under water, of vegetable matters, and now enormously increased in amount by the small depth of water covering.

Either one of these three causes, or all combined in varying proportions, might reasonably be regarded as efficient to produce the mortality witnessed. As a fact, with regard to the first cause, or organisms produced in waters and acting as specific fish poisons, little as yet is definitely known. The second hypothesis, that the mortality is due to decaying vegetable matters disseminated through the waters in excessive amounts at certain seasons, is advocated by many pisciculturists. The third, or deoxidation theory, is not without plausible grounds of support. Moreover, no complaint was made either of the appearance, taste, or odor of the water.

It is evident from the foregoing that there is urgent need, and immediate practical use, of more precise knowledge concerning the mutual dependence of plant- and fish-life in river water, and their relation to its condition of aeration.[1]

A beginning appears to have been made in this direction, by the examination of the water supply of New York and Albany, when contaminated by vegetable matters, some account of which will be found in the report of the Water Board of the former city for 1859, and in that of the latter, for 1865. In the former report, Prof. John Torrey attributed the musty odor and unpleasant taste, which characterized the Croton water during the month of August, 1859, to the

[1] For description of algæ, see "History of the Fresh Water Algæ of the United States," Prof. H. C. Wood, published by Smithsonian Institution.

rapid development of a bright green vegetable substance, diffused through the water and accumulated in large amounts on the surface of Croton Lake and elsewhere. The water in the lake at the time was very low, only a small portion going over the dam. Dr. Torrey says: "I think we are warranted in concluding that the recent offensive condition of the Croton water was owing to a rapid and abundant growth of a microscopic, conferva-like plant, which abounds in a volatile, odorous principle, soluble to some extent in water." This plant, Dr. Torrey referred to the genus Nostoc. He moreover thought it probable that it occurred more or less every summer, but only occasionally, by excessive growth, communicated an offensive odor and taste to the water, and was thus brought into popular notice. Even in this case, he did not believe that it communicated any unwholesome quality to the water.

Quite recently, during the summer of 1876, the water supply of Boston becoming deteriorated, Prof. Nichols, of that city, was requested by its Board of Water Commissioners to examine into the sources of the trouble. It had been previously noted that in the months of October and November, 1875, the drinking-water of the city of Boston had a taste resembling that of cucumbers. A similar taste, it is said, had been noticed as far back as the autumn and winter of 1854. When the taste reappeared in 1875, an examination of the water was made by Prof. W. R. Nichols, Mr. Edward Burgess, and Prof. W. G. Farlow, to ascertain whether any substance known to chemistry, zoology, or botany, could have produced the peculiar cucumber taste. They reported that no assignable cause could be discovered, but that, as far as the botanical examination showed, the water was unusually pure; that from the Bradley basin, where the cucumber taste was strong, being decidedly more free from vegetation, whether living or dead, than that from the Brookline Basin, where the taste was not perceptible.

"It has long been believed," Prof. Farlow remarks,[1] "that the algæ known as nostocs have a disagreeable odor, and, in many cases where unpleasant odors have arisen in bodies of water which serve as water supplies, it has been considered a sufficient explanation to say that the odor is produced by some nostoc-like plant, without, however, going so far as actually to find the plant which is supposed

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[1] Bull. Bussey Institute, January, 1877.

to be a nostoc. Undoubtedly, the most disagreeable odor ever found in fresh water, may be produced by nostocs, using that word to designate the order Nostochiniæ, but by no means all the disagreeable odors and tastes arise from that source. As to the cucumber taste, there is not the slightest proof that it is caused by any algæ, either living or decaying.

"As far as smells are concerned, our knowledge is more complete. It is known that, when living, different species of nostoc may produce two different kinds of disagreeable odors: first, an indescribably suffocating odor, as in the case of several Lyngbyæ and Oscillariæ; and secondly, a sulphurous odor, as is given off by species of Beggiatoa. A still more disagreeable odor, resembling that of a pig-pen, is given off by species of nostoc in decay. These are Oscillaria, which appear as bluish-green masses growing on the mud or in shallow water.

"The algæ which exhale sulphurous odors belong to the genus Beggiatoa, which resembles Oscillaria in consisting of filaments endowed with motion, but which differs in color, being whitish, the cells being full of opaque granules. They look to the naked eye like white films covering decaying algæ and other plants. It has been shown, by Cramer, that the dark granules in species of Beggiatoa consist of sulphur. When Beggiatoa filaments are heated, the granules fuse into large yellowish drops and a sulphurous smell is developed."

In the summer of 1876, the trouble was particularly noticeable in the waters of Horn Pond, the head-waters of what is known as the Mystic Basin, which supplies Charleston and East Boston. "It was stated that a disgusting odor, said to resemble that of a pig-pen, had appeared in several portions of the pond, and it was found that a quantity of a plant called eel-grass had been washed ashore, and upon it was a slimy mass from which the odor seemed to proceed. This so-called eel-grass was not the flowing plant generally known by that name, the Vallisneria Spiralis, but a new species of Plectonema, of the order Nostochiniæ. It grew in great abundance at the head of the pond where the water was shallow, attached to other plants and sticks, and spread over the surface in areas of several square feet, forming blackish-green patches. Where the Plectonema was free from the slimy substance, it emitted the suffocating smell of many of the Oscillariæ, but was devoid of the pig-pen odor.

"In various places along the edge of the pond, and in some places where the Plectonema came to the surface, were masses of slime, at first of a pale bluish-green, afterwards of a brownish color, and emitting a most disgusting odor. This slime was composed of an amorphous mucus, made up of aggregations of decaying filaments, belonging to a species of Anabæna, or some nearly related genus, like Nodularia Litorea. It was shown by Dr. Bornet that the intensely disagreeable odor prevalent near Deanville, in Normandy, during August, 1874, was due to the decomposition of large quantities of the latter algæ.

"Early in October, the Anabæna had completely disappeared. Furthermore, the Plectonema, which, in August, was attached, was washed ashore in immense quantities, leaving the surface of the pond clear. A quantity of the Plectonema was kept for some time until it began to decay, when it began to give off the pig-pen smell, which could hardly have arisen from any remains of the Anabæna, as a microscopic examination showed no traces of it. It would seem then that the peculiar odor, which was so marked in the case of Horn Pond, may arise from decay of more than one species of the Nostochiniæ, and the probability is that a large number of species may produce it. The important point is that it is during their decay that the odor is found, not while they are growing. The question arises as to what killed the algæ so suddenly. Those living near the pond are ready to believe that it was the refuse from the tanneries, but there is no proof whatever that that was of a different character from what it had been previously, and the question is still open, why, at that particular time, the algæ were killed. It will be remembered that during the month of August, 1876, the heat was excessive, and the temperature of the surface water was raised considerably. We cannot doubt that the boiling rays of the sun had a destructive effect on the Anabæna, especially that which was caught in the meshes of the Plectonema, and, by the falling of the water consequent upon the drought, exposed on the surface.

"Some words, as to the remedies to be applied in similar cases, may be of service. If a sudden odor of pig-pen arises, it is, in all probability, owing to the decay of large quantities of some algæ of the nostoc family, and most probably one of the finer species diffused through the water. As the decay is generally, if not always, brought about by causes beyond human control, it is useless to try to stop it

when it has once begun. On the other hand, there is no occasion for great alarm; for when they have once begun to decay, algæ like Anabæna disappear in a few days. Knowing that floating algæ are caught in the meshes of Plectonema and similar filamentous algæ, and thus during the sinking of the water, which usually occurs in July and August, exposed on the surface to the direct heat of the sun's rays, which cause them to decompose, it is evident that it is a useful precaution to remove, as far as possible, the long filamentous algæ and fine-leaved phanerogams.

"There is another plant which forms a bluish or yellowish-green scum on the water, often spread over a considerable area. Were it not that it forms such a thin layer, it could be collected in large quantities. Kept in bottles, it multiplies and forms irregular masses of a pea green color and mealy consistency. At first solid, the superficial cells imbedded in a gelatinous mass increase rapidly, and it becomes hollow. Then certain portions project like buds, and finally separate from the mother plant which seems to be perforated. This plant, Clathrocystis Æruginosa, was described by Henfrey, and is now classed by Cohn among the Bacteria, and placed near Clathrocystis Roseo-persicina, a plant which forms purplish-red films on decaying algæ, and on the ground along our coast, and which in Europe is also found in fresh water, but it has not yet been found in the interior of our own country. We mention it from its frequent occurrence, and because it has been supposed to injure the water in some places. There is no account of any injury having been done to man; but in Germany, where it is known as the Wasserblüthe, it has been destructive to fishes. It has been suggested by Cohn, in his Berträge zur Biologie (Vol. I, Part III, p. 155), that the slimy substance of which it consists forms a coating over the fish, and shuts off the supply of air necessary to support life. Professor Hagen, of Cambridge, suggests, as a remedy, the introduction of snails into water where it occurs, as they are extremely voracious, and eat large quantities of fresh-water algæ."

These investigations concerning the fresh-water algæ, and their connection with and interdependence upon the animal life of streams and upon their dissolved oxygen, are of great importance. Upon them the solution of many unsolved problems of water-pollution and water-purification largely depends. The previous methods of dealing

with these problems are eminently unsatisfactory and inconclusive.[1]

It is stated above that the deterioration in river water is accompanied by the development of certain lower orders of vegetable life. Along with this, there appears to be a corresponding change in its fauna, and along with both, a diminution in the percentage of dissolved oxygen. It has long been supposed that dissolved oxygen played a great part in the purification of streams, and that it was the principal agent by which putrefiable substances were broken up and converted into harmless inorganic compounds. A recent essay by M. Gerardin, to which the prize was awarded by the Paris Academy of Sciences, contains some striking results. To summarize, his methods of inquiry were:

1. A determination of the amount of oxygen held in solution.
2. An observation of green plants and aquatic mollusks.
3. A microscopic examination of algæ and infusoria.

It is claimed that the results obtained by these three methods were identical, and that, where the water was clear, with abundance of fish, water-cress, etc., it contained a correspondingly large amount of oxygen; while in places where the dissolved oxygen was small, fish and the higher types of aquatic plants were wanting, and certain low forms of vegetable growth had taken their place. The river Vesle, in France, from Rheims to Braisne, was taken as the field of observation. It was studied over a distance of 37½ miles, during which it received the sewage of one large town (that of Rheims), amounting to 4,180,000 gallons, and other impurities. Above Rheims, the water (which was clear, wholesome, and with abundance of fish, charas, water-cress, iris, etc.) contained 1 cubic inch of oxygen in 100 cubic inches.

In passing through a suburb above Rheims, the Vesle received the refuse of some dye-works, which colored the water; and in place of the fish and water-cress, Sparganium Simplex made its appearance. At a point where the water had received the contents of the five principal sewers of Rheims, the water was thoroughly polluted and contained but ·05 cubic inch of oxygen in 100 cubic inches. Two species of algæ, the Beggiatoa Alba and the Oscillaria Natans, were developed largely, the latter to such an extent, that the whole surface of the sluggish water was covered with a thick blackish coat.

[1] See article entitled "Recent Progress in Sanitary Science," *American Chemist.*

This coat was seemingly so solid, that animals, and even men, ventured upon it, mistaking it for terra firma. Above the mill at Macan, where the oxygen had increased to 0·74 cubic inch, the two varieties of algæ mentioned above had disappeared, and the bed of the Vesle was covered with a long, whitish alga, called Hypheothrix. At Compensé mill, the oxygen had increased to 0·8 cubic inch, the Hypheothrix had almost completely disappeared, and the Sparganium Simplex was again abundant. Below this point the amount of oxygen increased, and with it a corresponding change took place in the vegetation until, at Braisne, the water contained 1 cubic inch of oxygen per 100 cubic inches, all traces of pollution had disappeared, and fish and water-cress flourished. From this it would appear that a properly aerated and pure water showed, when polluted, the amount of pollution by a corresponding diminution of oxygen, by the appearance of Sparganium Simplex, Spirogyra, Hypheothrix, Beggiatoa and Oscillaria, and progressive improvement by a corresponding increase of oxygen, and the appearance of these plants in reverse order.

In view of the preceding facts we think that there ought to be a certain reform in the method of examining into the potability of water supplies. In the larger number of cases the great expenditure of labor upon the percentage determination of the mineral constituents, which are generally small in amount, except in turbid streams containing much earthy matter in suspension, or in springs deserving the appellation of mineral- rather than of drinking-waters, might be omitted. The estimation of the constituents upon which the hardness depends, relates to their employment for household and manufacturing purposes, and is not connected with our present inquiry. The time thus saved might be expended in making *comparative* determinations of the water under examination, at a point *above* where it can be suspected of having received contamination, and *after;* of the chlorine, nitrous and nitric acids, dissolved oxygen, etc., and generally of those constituents whose determination is essential to the main question. Furthermore, while admitting the great value of the "ammonia" and "albuminoid ammonia" processes in many cases, as in the determination of the contamination of wells by sewage, yet there is much reason for believing that an organic analysis of the residue affords a safer ground of comparison. These points, however, require further investigation.

ON THE RELATION OF MOISTURE IN AIR TO HEALTH AND COMFORT.

By ROBT. BRIGGS, C. E., Cor. Mem. Am. Inst. of Architects, etc.

In continuation of the paper read before the American Institute of Architects,[1] which has appeared in the three previous numbers of this JOURNAL, it is desirable to support the argument for the impracticability of attaining the full summer condition of humidity, for air in winter which has been warmed to the temperature of comfort, by more extended computations than could be presented to an audience, or brought within the scope of comprehension of the listener or the casual reader. The single example with specified relations, which was taken, showed, on calculation, that nearly as much heat would be expended in supplying vapor for the usual hydration of air of usual humidity and of 34° temperature (which air was heated to 70°), as was expended in heating the air itself.

The temperatures, and humid condition of about 69 per cent. assumed, being the averages of nature, out of doors, for three warm or three cold months, in the city of Philadelphia, in 1844, as reported by Prof. Bache. It occurs, accidentally, that the exact conditions of temperature and humidity chosen for an example, give the ratio of heat demanded for the two purposes incident to warming air as unity, while this ratio, for other temperatures and degrees of humidity, will be found to vary materially. For the purpose of exhibiting more completely the general case, the accompanying table has been prepared to show what quantities of heat are demanded for heating, or are given out in cooling air of 70 per. cent. humidity, from various temperatures (from 0° to 100°) to 70°, in direct comparison to the quantities for vaporization or condensation of water to procure the condition of 70 per cent. humidity to the air of 70°. When 70° and 70 per cent. humidity may be accepted as the American summer condition of comfort for the air; it being asserted that 70°, with 80 per cent., or more, of humidity, is close and enervating, while 70°, with 60 per cent., or less, of humidity, is fresh and cool, and demands heavy clothing to preserve the comfort of the individual—a proper and necessary demand in winter.

[1] At the Meeting of the Institute at Boston, October 18th, 1877.

Table.

Volume and Weights of Air and Vapor of Humidity—Temperatures of Saturation and Dew Point—Heat to be Expended in Warming or Cooling Air or Vapor to the Temperature of 70° Fahrenheit and Condition of 70 per cent. Humidity.

I.	II.	III.	IV.	V.	VI.	VII.	VIII.	IX.	X.	XI.	XII.	XIII.	XIV.	XV.
Temperatures in degrees, Fahrenheit.	Volume of dry Air to one Pound. Barometer 29·922 inches.	Weight of dry Air per 1000 cubic feet. Barometer 29·922 inches.	Force of Vapor in inches of Mercury Column.	Weight of Vapor in 1000 cubic feet = quantity of Vapor in saturated Air.	70 per cent. of weight of Vapor in 1000 cubic feet = quantity of Vapor in air of 70 per cent. humidity.	Weight of 1000 cubic feet of Air of 70 per cent. humidity, including its vapor. Barometer, 29·922 inches.	Weight of dry Air in 1000 cubic feet of Air of 70 per cent. humidity. Barometer, 29·922 inches.	Weight of Vapor accompanying 73·63 lbs. of dry air at given temp., and 70 per cent. humidity. Barom., 29·922 in.	Percentage of volumes of Air of 70 per ct. humidity displaced by the presence of aqueous vapor. Barom., 29·922 in.	Temperatures of Saturation in degrees Fahr. = Dew Point of Air of various temperatures, and 70 per ct. humidity.	Temperature of indication of Wet Bulb Thermometer, taken from Glaisher's tables.	Weight of Vapor to be supplied or taken from 1000 cu. ft. of Air, when brought to 70° Fahr. to make quantity needed for 70 per cent. humidity.	Heat units for warming or cool'g 0·07363 lbs. of Air with its accompanying vapor from given temp. to 70° Fahr.	Heat units demanded for vaporization or condens. of vapor to give 70 per ct. humidity to one cu. ft. of Air of 70° F.
0	11·577	86·38	0·045	0·081	0·057	86·35	86·29	0·048	0·11	......	......	0·749	1·228	0·797
5	11·704	85·44	0·054	0·095	0·067	85·40	85·33	0·058	0·13	......	......	0·739	1·141	0·787
10	11·830	84·53	0·067	0·118	0·082	84·48	84·40	0·072	0·16	1·1	8·8	0·725	1·054	0·772
15	11·957	83·64	0·085	0·148	0·104	83·58	83·47	0·092	0·20	7·3	13·9	0·705	0·966	0·751
20	12·083	82·76	0·108	0·186	0·130	82·68	82·55	0·116	0·25	12·4	18·9	0·681	0·879	0·725
25	12·210	81·90	0·136	0·232	0·162	81·80	81·64	0·146	0·32	17·2	23·5	0·651	0·792	0·693
30	12·336	81·06	0·169	0·285	0·199	80·94	80·74	0·182	0·40	21·8	27·7	0·615	0·704	0·655
32	12·387	80·73	0·183	0·308	0·216	80·60	80·38	0·198	0·43	23·6	28·8	0·599	0·670	0·638
35	12·463	80·24	0·207	0·345	0·242	80·10	79·85	0·223	0·49	26·5	25·	0·574	0·617	0·611
40	12·590	79·43	0·251	0·415	0·290	79·26	78·96	0·271	0·59	30·8	30·1	0·526	0·529	0·560
45	12·716	78·64	0·302	0·494	0·346	78·43	78·08	0·326	0·71	35·5	34·6	0·471	0·432	0·501
50	12·843	77·87	0·362	0·587	0·411	77·62	77·21	0·392	0·85	40·3	45·	0·405	0·353	0·432
55	12·969	77·11	0·433	0·695	0·487	76·82	76·33	0·470	1·01	45·1	49·	0·328	0·266	0·349
60	13·096	76·36	0·517	0·821	0·575	76·02	75·44	0·561	1·21	50·0	54·	0·236	0·178	0·251
65	13·222	75·63	0·616	0·968	0·678	75·22	74·54	0·669	1·44	54·9	58·5	0·127	0·088	0·136
70	13·349	74·91	0·732	1·138	0·797	74·43	73·63	0·797	1·71	59·8	63·	0·000	0·000	0·000
75	13·476	74·21	0·867	1·336	0·935	73·65	72·71	0·946	2·03	64·7	68·	0·149	0·090	0·159
80	13·602	73·52	1·023	1·562	1·094	72·86	71·77	1·121	2·39	69·5	72·5	0·324	0·181	0·345
85	13·729	72·84	1·203	1·822	1·275	72·07	70·80	1·326	2·82	74·2	77·5	0·529	0·272	0·563
90	13·855	72·17	1·410	2·117	1·482	71·28	69·80	1·563	3·30	78·9	82·5	0·766	0·365	0·816
95	13·982	71·52	1·647	2·452	1·716	70·49	68·77	1·837	3·85	83·7	87·5	1·040	0·460	1·108
100	14·108	70·88	1·918	2·828	1·980	69·69	67·71	2·152	4·49	88·4	92·5	1·355	0·556	1·443

The figures relating to weights in the foregoing table, refer to 1000 cubic feet (a cube of 10 feet side) for a unit, to avoid the repetition of 0's in decimals; by multiplying any value by 7, the weights per cubic foot in grains will be found. All the weights are in pounds avoirdupois and decimals. The volumes are in cubic feet.

Columns II and III are derived from Regnault's data; weight of one cubic foot of dry air = 0·080728 pound = 12·387 cubic feet per pound; and rate of expansion = 0·002039 volume for each degree Fahrenheit from 32° = 0·025315 cubic foot per pound from 32°.

Column IV is taken from Guyot's tables, Regnault's data, slightly corrected by differences.

Column V is derived from $W = \frac{0{\cdot}622}{29{\cdot}922} \times$ value of Column III $\times$ value of Column IV, where 0·622 = specific gravity of vapor in air of the same tension; and 29·922 = inches of mercury column which measures the tension of air in Column II.

Column VI is obtained directly from Column V, as indicated in caption.

Column VII is obtained by taking the difference of weight of the volume of vapor in the air, from that of the air which it displaces, and deducting their difference from the respective values in Column III. The values in Column VII agree as closely as could be expected with results in Glaisher's tables.

Column VIII is obtained by deducting weight of vapor, Column V from Column VII.

Column IX is obtained by taking the ratio of quantity of dry air in the several values of Column IX, with the value at 70° (= 73·63 pounds) as a unit, and dividing by this ratio the values in Column VI.

Column X is obtained by taking 70 per cent. of $\frac{F}{29{\cdot}922}$, where F is the tension of vapor possible to exist at the given temperature, as given in Column IV, and 29·922 is the tension of the atmosphere. It should be noticed that this column has its units in percentages: the first value, for instance, is $\frac{11}{100}$ of a per cent.

Column XI is obtained by making a computation of three columns for saturated air, like VII, VIII and IX, and thus ascertaining at what degree of temperature the values in Column IX coincide with those in the same column for saturated air. This column closely agrees with Glaisher's, varying two degrees higher at 15° and corresponding at 80°.

Column XII is taken from Glaisher's tables at 70 per cent., and is sufficiently exact for use.

Column XIII is obtained by taking the difference between the quantity of vapor in air of 70° Fahrenheit, and that in the several values given in Column IX.

Column XIV is obtained by multiplying 0·07363 pounds (the quantity of dry air in a cubic foot of air of 70° Fahrenheit and 70 per cent. humidity) by 0·238 (the specific heat of air), adding to this value, that of the amount of the several values in Column IX, multiplied by 0·475 (the specific heat of vapor), and then multiplying the sums of the above by the number of degrees from 70° which the air is to be heated or cooled.

Column XV is obtained by multiplying the values of Column IX (the vapor to be supplied or removed) by 1065° = the latent heat of steam from and at 70°, and dividing the result by 1000, so as to give the heat of vaporization belonging to one cubic foot of air at 70°.

A careful study of the table, with comparisons of the values given in the several columns, will readily allow any student to find the fullest corroboration of the views expressed in the original paper; but for the convenience of the general reader, it may be well to exhibit some of the results. Thus, calling attention to Column XI, it will be seen that the air of saturation at 60° becomes, by heating, that of 70° and 70 per cent. humidity; showing a close approach of English and American humid conditions to the comfortable condition in either case. Again, the temperature of saturation for air of 80°, with 70 per cent. humidity, is 69·5°; consequently, air of above 80° of the usual humid condition of our climate in summer, will become a mist and rain, unless its moisture be absorbed by some non-heat-giving absorbent. If such air is to be reduced to the 70° standard of comfort, by means of surfaces cooled by currents of water, such surfaces must have a temperature at least below 60°, and probably 10° below that point, to abstract, by condensation, the moisture from the air. The heat demanded for condensation, therefore, will be increased some 20° below that of cooling the air, but as the latent heat of vapor of water is nearly constant, the difference of quantity of heat for cooling is not materially changed.

A study of the last two columns will demonstrate that as the quantity of moisture present in air falls off much more rapidly than the temperature, the quantity which is requisite to make up the moisture in air at 70° and 70 per cent. humidity, from the condition at the various temperatures with the same ratio of humidity, becomes more and more nearly the same as the temperatures fall off. The great heat demanded for changing water into vapor accordingly, is nearly constant for the low temperatures, and the heat demanded for warming

air gains on that for vaporization of water; and after passing a greatest difference at between 55° and 60°, attaining an equality at about 36°, it becomes about one-half greater at 0°.

The tabular values here given have, it is thought, been first grouped together in this, or any form, and they will be found a ready and convenient basis for the application of the various meteorological conditions to warming and ventilation.

COMPARATIVE EFFICIENCY OF SCREW PROPELLERS WITH TWO AND WITH FOUR BLADES.[1]

The records of experiments in screw propulsion contain little to parallel the anomalous results obtained with the twin-screw dispatch vessel *Iris*. This ship was intended to attain a velocity of 17·5 knots an hour with 7000 indicated horse power. She was built on lines suggested by Mr. Froude, as the result of an elaborate inquiry into the laws of fluid resistance to floating bodies; and it was anticipated that every expectation formed concerning her would be realized. When she was tried on the measured mile for the first time, although her engines worked up to 6880 horse power, the ship reached a speed of but 16·45 knots; and as the speeds vary about as the cube roots of the powers, it was evident that a power of about 8250 horses was the least that would suffice to drive her at 17·5 knots an hour, which power could not be got from the engines. Much disappointment was felt, and various explanations were put forward to account for the shortcomings of the ship. It is generally known that twin screws are not on the whole so efficient as single screws, because they cannot be used without some arrangement to carry them outboard, either in the shape of wrought iron brackets or stern tubes, or both, and these appurtenances obviously increase the resistance of the ship. But for this Mr. Froude allowed in his calculations, or more properly speaking, it was assumed that the lines which he had laid down for the ship would prove so excellent that notwithstanding the presence of stern tubes, the *Iris* would steam as fast, power for power, with twin screws as if she had been fitted with one screw. We have seen that this theory was hardly supported by the earlier trials of the

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[1] From the *Engineer*.

ship. It was also suggested that the screws themselves were in fault, and that they would prove more efficient with two blades each than with four blades. Little could be urged in favor of this theory. An eminent authority has stated that between the best and the worst formed screw there is not ten per cent. difference in efficiency, the pitch being the same. In normal practice it is known that propellers, whether they have four, three or two blades, are about equally good, and that the number of blades is settled as a rule by considerations which have little or nothing to do with efficiency, but refer to vibration and its prevention more than to anything else. To assert, therefore, that much improvement would be effected by taking two blades off each screw of the *Iris* appeared preposterous. Indeed, there was some reason to think that quite as much would be lost by augmented slip as could be gained in any direction. However, the experiment would cost very little, and so it was made, with, as we have said, results which are, we believe, without any parallel. The second speed trial of the ship took place on Friday, the 15th of February. We have already published the figures, but for convenience we reproduce them here—giving, for simplicity sake, only round numbers concerning the engines. On the first trial, the engines making 43 revolutions per minute indicated 768 horse power, and the speed of the ship was 8 knots. On the second trial, with 45 revolutions, and 604 horse power, the speed was 7·95 knots, or practically the same as on the first trial. Thus, 164 horse power was saved. On the first trial, with 65 revolutions, and 2561 horse power, the speed was 12 knots. On the second trial, with 65 revolutions, the power was 1661, and the speed 11·759. Here a loss of less than a quarter of a knot an hour was accompanied by a saving of as much as 900 horse power. On the first trial, with 82 revolutions, and 5210 horse power, the speed was 15·123 knots; on the second trial, with 81 revolutions, the power was 3335, and the speed 14·507 knots. Here we have a loss of ·616 of a knot, and a reduction of 1875 horse power. Finally, in the last trial, with 89 revolutions, and 4400 horse power only, a speed of 15·726 knots was obtained. As it was not considered advisable to run the engines faster than 89 revolutions per minute, the experiment terminated here. It will be seen that a velocity less by ·724 knot than that realized with four-bladed screws was obtained with the altered propellers, with 2480 horse power less. If

the two-bladed screws prove equally efficient, when their pitch has been altered from 18 ft. to something sharper—which will permit the engines to work up to a higher power without making more than 88 or 90 revolutions—the intended speed of 17·5 knots should be obtained with about 6200 indicated horse power, or, say, 2000 horse power less than would have been demanded by four-bladed screws.

An examination of the figures will show that the results are somewhat lacking in uniformity. Thus, if we take the first pair of experiments, it will be seen that very little, if any, advantage was gained. The speed with the two-bladed screws was slightly less than when four blades were used, and the power was also less. Setting the two against each other, it may be said that no advantage whatever was gained by the change; and had the experiment ended here —as it might very well have done had it been carried out with a cargo steamer instead of with what is intended to be the fastest ship in the British navy—it would have been taken as proved that there is nothing to choose between four blades and two blades. The facts are instructive, as showing how easy it is to draw erroneous conclusions from incomplete data. In the second series of experiments, the power with two-bladed screws was 1661 for a speed of 11·76 knots. Had the speed been 12 knots, the power would have been about 1750 horse power, so that the true saving amounts to 811 horse power. Here the gain is enormous, and, as we go on step by step, so does the benefit increase, and it thus becomes evident that what holds true of screws running at slow velocities, by no means holds good for screws revolving rapidly. Again, it will be seen that, notwithstanding the loss of one-half the propelling area of the screws, the slip was not increased to any serious extent. Thus, at 8 knots the engines made but two revolutions per minute more with the reduced screws than they did with the unaltered propellers. The slip was thus augmented 36 ft. per minute, or less than one-third of a knot per hour. At 12 knots the slip was but slightly augmented. Practically it may be said that no loss of any kind worth mentioning ensued from the change.

We are thus brought face to face with the fact that the four blades which were removed required nearly 2000 indicated horse power to work them, and we have to consider in what way this enormous power was expended. The problem is one far from easy of solution.

It is impossible to maintain that it was wasted in overcoming the surface friction of the propeller blades in the water. If that were so, then the remaining blades must continue to offer the same proportionate frictional resistance; and of the 4400 horse power actually exerted by the engines of the ship on her last run, nearly 2000 would be wasted, and only 2400 horse power net would be left for other resistances and for propulsion, which is absurd. In the runs when the speeds were nearly identical, the thrusts must also have been nearly identical. The efficiency of both the four-bladed and the two-bladed screws was therefore so far the same. The defect of the former lay in the fact that much more power was required to turn them than sufficed with the latter. It may be argued, perhaps, that this statement is not accurate, and that the four-bladed screws really exerted a much greater thrust than their fellows, but that they operated in some unexplained way to prevent the influx of water to the ship's stern, and so increased her resistance. We see no ground whatever for this theory. The only feasible explanation of the phenomena appears to us to be that which we have already stated—the screws were harder to turn round with four blades than with two blades. Why they were harder to turn is quite another point, which we are unable to determine with certainty, nor are we aware that any one else is in a better position. The problem deserves the most careful investigation, and we have no doubt it will receive it from Mr. Froude. But it is clear that the abnormal resistance did not materially affect the performance of the screw as an agent for giving a thrust. Yet if so much of the power had been wasted in what is known as "churning" the water, it seems probable that the thrust would have been diminished. On further examination we believe it will be found that the four-bladed screw was hard to turn, because it carried round with it a great deal of water. In other words, as it progressed ahead it continually imparted a motion of rotation to successive bodies of water previously at rest, or moving in easy curves or right lines. The two-bladed screw does not do this to the same extent, because it is deficient in what may be termed transverse or projected area. In other words, the power of the engines was wasted in putting water in motion in a direction not parallel with the keel, and this motion was useless as a means of producing thrust.

INCRUSTATIONS ON BRICK WALLS.

By William Trautwine.

The disfiguration of brick house fronts, by white incrustations, is now so general that it is to the interest of the public, and of brick-makers and builders particularly, that its causes shall be determined and a remedy applied, so that, if possible, houses built hereafter may be free from it. Many recent attempts at ornamental brickwork have resulted only in unsightly walls. The incrustation has been variously discussed in the newspapers, but owing to conflicting views of its causes, builders, brick-makers and bricklayers appear still to doubt the efficacy of any remedy hitherto proposed. It is desirable that all observed facts and statistics of attempted improvements should be collated and reviewed by some competent authority.

This defacement is most noticeable in dry weather on parts of walls subjected to dampness, and on entire walls after rain-storms have soaked them. North and east walls are coated on drying after north-east storms. Chimney walls and chimney tops, lines of leaky or obstructed water-spouts, spaces beneath window-sills, walls near the pavement, and pavement bricks, are especially marked. The white coating is derived primarily from both bricks and mortar, and in some cases it is difficult to decide, without dissecting the walls, whether the bricks, the mortar, or both, are or are not concerned. The Bankers and Brokers' building, opposite the Stock Exchange, is not yet completed, but its walls are already unsightly with white patches. The black mortar or cement with which they are pointed has disintegrated and crumbled out here and there, leading to the conclusion that this is chargeable with the defacement. The bricks, however, are coated where the pointing is not at all affected, and one particular brick, which was left out of the wall, and was faultless in form, color and consistency, showed white patches when it dried after having been wet.

It will be found most convenient to consider first, the incrustation as derived originally from the bricks. It is most conspicuous on comparatively new walls. It may be observed in the outskirts of the city, on very new walls of unfinished houses in which no fires have burned, and where the mortar is unchanged. In these cases the

white substance is dissolved by moisture from the bricks, which contain it before they are built into the houses. The writer has visited several brick-yards in the suburbs, where piles of new bricks, which had never been in contact with mortar, but remained in a comparatively pure atmosphere since leaving the kilns, showed the common white incrustation. Some of the bricks which remained in the kiln were also coated. In several yards the incrustation had, here and there, a yellow tinge, possibly from traces of oxide of iron or hyposulphite of lime. One of these bricks, taken hap-hazard, was examined somewhat in detail. The white coating had a peculiar taste, in which that of sulphate of magnesia (Epsom salts), though disguised, was recognizable. As this white substance had come out from within the brick, the latter was crushed and the debris digested in water. At the end of a week the water had dissolved out a mixture, consisting mainly of the sulphates of magnesia, lime and iron. This brick contained no traces of sulphites, soluble carbonates, or soluble chlorides. The white incrustation disfiguring several fine pressed bricks in a new wall was also examined. It had so saline a taste that most persons would have pronounced it common salt. Nevertheless it contained none. It was almost wholly sulphate of lime and magnesia, with traces of iron and alumina. No carbonates were present. Several other specimens of incrustation were examined, with the same results. Two specimens of incrustation were examined specially for soda and potassa, but neither contained noticeable quantities.

The fact being established that bricks burned with coal fires are impregnated with the soluble sulphates mentioned above, specimens of brick clay from the pits of different brick-yards were next examined, in order to determine whether, and to what extent, these salts originally exist in brick clay, or are produced when bricks are burned with coal fires. None of the specimens contained free sulphuric acid or appreciable quantities of soluble sulphates (such as the sulphates of magnesia, lime or alumina). They contained no soluble carbonate or chloride. Only minute quantities of insoluble carbonates (such as the carbonates of lime and magnesia) were present. Further examination proved that all the specimens consisted chiefly of clay proper, *i. e.*, silicate of alumina, with much oxide of iron, and small proportions of lime and magnesia, which, presumably, were also contained as silicates. The proportions of lime and magnesia contained in the clay—separated by long digestion with an excess of hot

sulphuric acid—about equaled those existing as sulphates in the aqueous brick solution; suggesting the inference that brick burning may, in some instances, convert all or nearly all the supposed silicates of magnesia and lime into sulphates.

The process of burning bricks with coal sufficiently accounts for this conversion. Nearly all coal contains diffused particles of sulphide of iron, or iron pyrites. These are decomposed when coal burns, and sulphurous acid gas is one of the products of the combustion. When sulphurous acid gas, air, moisture, and substances which have an affinity for sulphuric acid, are brought together at high temperatures, long sustained, sulphates of the susceptible substances are formed. The silicates of lime and magnesia are probably decomposed under these circumstances, sulphates of lime and magnesia being formed. while silica is liberated. It is, therefore, reasonable to suppose that when the dense, sulphurous vapors of a coal burned brick-kiln, which are suffocating outside of it, are diffused, with moisture and air around and through the clay of intensely heated bricks for the greater part of a week, the fires being maintained usually three days, and the kilns opened at the end of a week, a reaction takes place; and that when the bricks are turned out from the kiln, they are impregnated with the above named sulphates. When the bricks become wet, these compounds dissolve, and in dry weather, succeeding storms, the solution evaporating from the surface of the bricks leaves them coated with these white compounds.

Sulphate of magnesia possesses the peculiar property of efflorescing, or blossoming, in dry air. In this way a very small amount becomes conspicuous. Brick clays contain varying proportions of lime and magnesia, and the percentage of iron pyrites varies in different specimens of coal. Bricks may be noticed apparently overstocked with the sulphates of magnesia and lime. These are much whiter in dry weather than others surrounding them. Coal is now generally, if not universally, used here for brick burning in place of wood. Coal dust is commonly mixed with brick clay in clay pits, and may add to the production of sulphates within the bricks. The white incrustation, however, occurs on bricks in yards where coal dust is not mixed with the clay. It is not used in pressed bricks, and these are as frequently defaced as others. Common bricks, in back buildings, are coated with the white incrustation, but generally escape attention. Bricks least subjected to sulphurous vapors while burning, may

be less impregnated with the sulphates of magnesia, etc., than others.

The simplest way to get rid of the sulphates, so far as the bricks supply them, is to avoid producing them while manufacturing the bricks. Pressed bricks and others intended for ornamental purposes might be burned with wood or with coke, if free from sulphur, in separate kilns far away from places where coal is burned in considerable quantities. Unless afterwards exposed to an unusual amount of sulphurous vapor, they would probably undergo no change.[i]

It has been asserted that the white coating was formerly noticed on bricks burned with wood, but the evidence appears to be mostly the other way. It is quite possible, though, that a white efflorescence, derived from the mortar, may have been observed on old wood-burned bricks; or that such bricks in rare instances have been specially subjected to sulphurous vapors, and thus altered.

It has been suggested that the white incrustation results from chemical change effected in bricks by sulphuric acid vapors in the air—derived from coal burned as fuel and from the combustion of illuminating gas. If the gas is properly purified at the gas-works, little sulphuric acid can be traced to it. Much more is generated by burning coal in houses and factories, but it is at least doubtful if much change is effected by it in bricks, particularly after its diffusion, though there is no doubt of its effect, in time, upon mortar, as explained hereafter. We have seen that bricks now generally contain enough of the unwelcome sulphates before they are placed in walls, and that, in some instances, all the susceptible magnesia and lime in them are then already converted into sulphates. The small amount of sulphuric acid diffused in the air is insufficient to produce any effect until after long exposure, yet new bricks are more disfigured than old ones. Silicates of lime and magnesia in the semi-vitrified bricks are somewhat protected from the action of the air. It is questionable, on the principle of elective chemical affinity, whether these silicates, even if more exposed, would undergo decomposition in the presence of the more vulnerable mortar. Some bricks, however, may contain free lime and magnesia.[ii] If the atmospheric acid vapors affected silicate

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[i] Clay sometimes contains iron pyrites, and its decomposition results in the formation of sulphates. Such clay is, of course, unsuitable for bricks intended for house fronts.

[ii] The writer does not assert that the magnesia and lime found by him in the clay specimens existed as silicates. This point was not determined, and is assumed only because no carbonates or sulphates of magnesia or lime were found in the clay.

of magnesia in bricks, serpentine stone fronts—almost wholly silicate of magnesia—would be much more affected. Many of these have been carefully examined, but in no case were the stones altered. Sometimes, the thick lines of mortar between them being decomposed, solution of sulphates from these had washed over the stone-work and defaced it.

Sulphate of magnesia is largely produced by the decomposition of mortar. Most of the lime used here is burnt from magnesian limestone, obtained in this vicinity, and the result is a mixture of lime and magnesia in varying proportions. The limestone belt of Chester Valley, which runs diagonally across the State, and which furnishes most of our lime, is largely magnesian limestone; the lower sub-division of the same formation in New Jersey being specially named the magnesian limestone in New Jersey geological reports. The mixture of lime and magnesia thus obtained, when slaked and made into mortar, is very susceptible to the influence of sulphurous fumes. These react, forming the sulphates of lime and magnesia. The great solubility of sulphate of magnesia facilitates its diffusion, and makes it the chief cause of defacement; sulphate of lime being comparatively insoluble. As the sulphate of magnesia dissolves and effloresces, the mortar is disintegrated. Sulphurous acid from coal burned in houses, produces its chief effects before it is diffused in the outer air. As it passes up through a chimney, it finds its way through crevices and pores in the wall, and thus directly attacks the mortar; sometimes causing the fall of chimneys, by eating out the mortar cementing them. The bricks, when damp, absorb sulphate of magnesia, or sulphate of magnesia and lime, from the altered mortar surrounding them. Sulphate of magnesia from altered mortar is most noticeable within doors, on chimney walls and in cellars, where the damp mortar is directly subjected to sulphurous vapors. Efflorescent crystalline masses of sulphate of magnesia often accumulate and protrude from between the loosening bricks.

Dampness produces a solution, which is sometimes diffused through a brick and makes its appearance outside, while the outer lines of mortar bordering the brick remain intact.[1] Several soft bricks in the outer wall of a chimney flue were examined recently. They were completely impregnated, as well as coated, with a white substance,

[1] Bricks readily absorb solutions, such as those of common salt, soap, etc., and these substances appear on the surface when the solutions evaporate.

which had disintegrated some of them, and which, on analysis, proved to be sulphate of magnesia, with traces of lime, alumina and oxide of iron. Sometimes, after long exposure, the outer lines of mortar appear to be directly affected by sulphuric acid vapors diffused in the surrounding atmosphere. Delicate crystals and protuberances of sulphate of magnesia and washings from these were observed on mortar lines in brick and granite garden walls, as well as on house fronts. Thick mortar lines in walls of brown stone buildings are much affected. Churches at Thirty-sixth and Chestnut Streets, Eighteenth and Columbia Avenue, and Franklin Street near Brown, will serve as illustrations. The Syenite retaining walls enclosing the Friends' Meeting House, at Seventeenth Street and Girard Avenue, and those of the House of Refuge on Poplar Street, show the defacement. In all these cases—particularly in the instances of the Syenite walls—sulphuric acid vapors clearly do not affect anything within the stones. In some cases mortar contains the sulphates of lime and magnesia before it is used. Most of our lime is burned with coal, and a half dozen specimens of quick-lime from different lime-kilns yielded slight traces of the sulphates of lime and magnesia. If we accept the development of these traces of sulphates in the lime by coal burning, mortar is probably made and used now about as it has been for many years past, excepting also that mud is sometimes used in place of mortar. Much more sulphuric acid, however, is now generated within the city limits, particularly in winter, by the greatly increased use of coal.[1]

To avoid this white defacement developed from mortar, builders should use lime, free from magnesia, in erecting exposed brick-work. A demand for such lime will bring ample supplies from other localities, and at low prices.

Continuous exposure to sulphurous vapors may effect some change even in mortar made from lime containing no magnesia. But, as before stated, the great solubility of sulphate of magnesia, and its tendency to effloresce, make it the chief evil, and it is worth while to try the result of using purer lime.

When argillaceous limestone is burned, hydraulic cement is formed. The resulting mixture of lime and burned clay (usually with some

[1] Rain absorbs acid vapors contained in the air through which it falls, and driving rains from the northeast may thus acidify, as well as moisten, north and east walls.

sand), when wet, "sets" compactly, and the admixture of clay may, to some extent, protect the lime from such influences as might otherwise affect it injuriously. Portland (hydraulic) cement is made by burning an artificial mixture of limestone (chalk) and clay. Portland cement is believed to contain but a small proportion of magnesia, and this circumstance, in connection with that of the possible protective influence of the clay, justifies the supposition that walls built with this cement, may show less white defacement than those in which our ordinary mortar is used. Several brown-stone base-walls, laid in good cement, and particularly exposed to dampness, were examined, but showed no defacement. The painted walls of a room in the building of one of the Trust companies in this city, lately became much disfigured by the formation of efflorescent crusts of sulphate of magnesia and lime, from the decomposition of mortar within the walls. At the writer's suggestion, hydraulic cement was substituted for the mortar, and the walls re-painted. This has since remained unaffected. Cements vary in price and quality, from good to worthless.[1] Chimneys might be laid in cement, and if white markings between the bricks are desired, these can be painted or pointed with marble dust. This is nearly pure carbonate of lime, and is used in mortar for pointing. It appears to remain a long while unaffected, indicating that sulphuric acid vapors in the air exert little influence upon it. Plaster (sulphate of lime) is not generally used for pointing. Unless largely mixed with mortar it would crack off or be dissolved, and washed by rain over the bricks. Paint serves to some extent as a protection from dampness. The disfigurement may, however, be observed occasionally on painted brick walls after damp weather, the paint being discolored, and in some cases thrown off by the incrustation forming beneath it.

The unsightliness caused by the white incrustations is intensified by contrast with what may be termed the black streaks. On almost every brick house these hang repulsively at either end of each window-sill. They represent the repeated washings of dust and dirt

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[1] White efflorescences, chiefly of the carbonates of soda and potassa, sometimes disfigure walls built with cement mortar. Rosendale cements frequently contain a large percentage of magnesia, together with soda and potassa. (*Vide* Gillmore on Limes, Hydraulic Cements and Mortars, N. Y., 1863.)

from window spaces and window frames. Scrubbing brushes, vigorously applied, might remove them. Any simple device would serve to divert the dirty drippings which soak the bricks beneath the windows, developing characteristic white patches here between the black streaks. As it is, the model Philadelphia brick house, with its white incrustations and black streaks, is a reproach and shame. Builders and brick manufacturers who prevent these evils in new houses, may reasonably expect to reap public gratitude, and, perhaps, something more satisfying. Entire blocks of houses have so changed countenance—have "so gone down"—within a single year, as to repel desirable tenants, when, indeed, they remained in all other respects unchanged. The subject under consideration has for a long time interested the writer from a utilitarian standpoint, rather than a scientific one.

EDISON'S CARBON TELEPHONE TRANSMITTER, AND THE SPEAKING PHONOGRAPH.

By S. M. Plush.

Both the telephone and speaking phonograph are instruments of American invention, and have undoubtedly excited more wonder and admiration throughout civilization than any previous inventions have done in ancient or modern times. Their novelty is still fresh, but when this fades away their practical uses will begin.

The telephone has already found its way into the counting-rooms and offices of our business and professional men, and reached almost the limit of its capacity. Quite recent improvements, however, have greatly increased its power, thus rendering it more efficient for all practical purposes, and widening the field of its usefulness.

These inventions, like all others, are not the result of one mind, nor the products of a day; on the contrary, they are the results of many men's diligent experiments, extending through a number of years. Based on the principle of the vibration of sound, Prof. Reiss, of Germany, constructed the first telephone in 1861. In this

instrument the electric current was broken by delicate springs, resting on a tightly-stretched membrane or diaphragm, which was thrown into vibrations corresponding exactly with the vibrations of the air, produced by the sound of the voice. The receiving instrument was constructed on the principle first demonstrated by Prof. Henry, that iron expands when under the magnetic influence of electricity, and returns to its normal condition when this influence is broken or removed. An electro-magnet, therefore, supported on a sounding box, and vibrated by these lengthenings and shortenings, made distinctly audible, at the receiving end, the vibrations of the membrane at the other.

This apparatus was capable of reproducing but one of the characteristics of sound, viz., pitch. Further experiment was necessary to reproduce its quality and dynamic force.

Elisha Gray, of Chicago, in 1874, gave to the world his harmonic telephone, based on the same general principles as that of Reiss. He succeeded in transmitting, at the same instant, several musical sounds of different pitch, and reproducing the same at almost any distance.

In 1876 came that of Prof. Bell, of Boston, consisting of a tightly stretched membrane, having a small permanent magnet fastened to its centre, in front of, and close to, the poles of an electro-magnet, charged by a galvanic current. Any disturbance or vibration of this membrane and permanent magnet, would necessarily induce a magneto-electric current in the coils of the electro-magnets and line, corresponding in all respects to the disturbing forces, in number, amplitude and duration of vibration, thus reproducing articulate speech. The receiving instrument consisted of a tubular electro-magnet of a single helix, surrounded by a soft iron cone, into the top of which was loosely fitted an iron plate, which was vibrated by the magnetizing action of the helix. Its capacity was extremely limited, the sounds were weak, and could be transmitted but a short distance. It, however, accomplished a great work in demonstrating the possibility of transmitting and reproducing articulate sounds.

Prof. Dolbear, of Boston, the same year, failing to see the importance of charging the line with a battery current, and believing it rather detrimental, substituted permanent magnets, with small electro-magnets around the poles, for the electro-magnets and galvanic

battery of Bell.[1] Another valuable improvement consisted in using the same instrument for sending and receiving, in lieu of instruments of different construction, as had been done previously.

As will be seen, when the vibrating motions of the air are concentrated on the diaphragm, as in speaking, a corresponding motion of it is produced; this, likewise, disturbs the magnetic condition of the magnetized bar, and induces electric currents in the surrounding helix, corresponding in all respects to the vibrations of the voice. Thus, by their electro-magnetic action upon an identical apparatus, placed in the same circuit, they will cause its diaphragm to vibrate in precisely the same manner as that of the transmitter. The principal peculiarity in this apparatus, and the one of vital importance to the transmission of articulate sounds, is that the electric current is never entirely broken, as is the case in the telephones previously described.

While all sounds may be faithfully transmitted and reproduced by this instrument, its capacity is not great, and when used on lines which are in close proximity to others heavily charged with electricity, the disturbing influence of induction is so great as to render these inaudible.

To overcome this difficulty, Thos. A. Edison, of Menlo Park, N. J., directed his attention to a series of experiments, and at length discovered that carbon, properly prepared, possessed the property of changing its conductivity by pressure, and that the ratios of these changes exactly correspond with the pressure brought to bear upon it. By varying degrees of pressure against a disc of carbon forming a part of an electric circuit, the resistance of the disc would vary exactly with the degree of pressure; a proportionate variation would, therefore, be occasioned in the strength of the current, which would thus possess all the characteristics of the vocal vibrations. By connecting this carbon disc in a local galvanic circuit, together with an induction coil, its power can be increased or diminished at pleasure. In its present state of development, conversation has been maintained between Philadelphia and Washington, a distance of 140 miles; while a magneto-telephone, placed in the same circuit, failed at 28 miles.

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[1] The improvement in the telephone here credited to Prof. Dolbear, is also claimed by Prof. Bell, and is embodied in the instrument described on p. 219, vol. civ., Oct., 1877, this JOURNAL. J. B. K.

Many modifications of the speaking telephone have been devised, but they all embrace one or other of the principles hereinbefore described. That of G. M. Phelps, New York, called the duplex telephone, characterized by its peculiar excellence of articulation, is perhaps the most prominent.

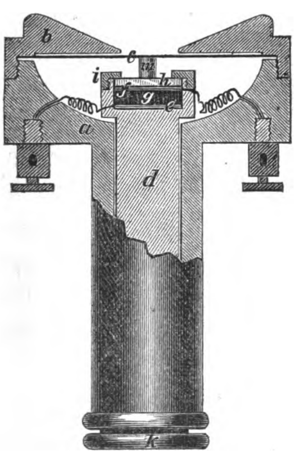
Fig. 1 represents the carbon transmitter of Edison, above referred to.

g, the carbon disc.

e and *f*, two thin platinum plates, connected in the local circuit.

Resting on the platinum, *f*, is a small disc of glass, *h*, of the same diameter as the carbon. On this glass plate rests a short brass tube, *m*, fastened to the round metal plate, *c*. This plate does not vibrate as the diaphragm in the ordinary telephone, being quite rigid; it simply arrests the atmospheric concussions, and conveys them, by direct contact, to the carbon disc.

FIG. 1.



b, the mouthpiece.

a, hard rubber case.

d, a core extending through the handle from the platinum, *e*, to the nut, *k*, to which it is connected by a movable screw, so arranged as to be capable of any desired longitudinal adjustment.

Edison's speaking phonograph is an invention of purely mechanical construction. By it can the voice not only be faithfully reproduced, but its records kept for centuries. It would be impossible to even conjecture the uses to which this wonderful instrument may be put. Time and the necessities of our people only, can determine this. It, like the telephone, depends for its action upon the vibrations of a metallic diaphragm, capable of receiving from, and giving to, the air, sound vibrations. It consists of a cylinder, Fig. 2, *a*, mounted on a horizontal axis, *b*, extending each way, beyond its ends, a distance of about its own length. In the circumference of the cylinder, a spiral groove is cut its entire length. The shaft is also cut by a screw-thread (16 to the inch) corresponding to the spiral groove of the cylinder, and works in screw bearings. When, therefore, the

cylinder is made to revolve by means of the crank attached to the end of the shaft, it moves horizontally to the right or left.

The diaphragm is supported in an iron box, mounted on a standard, *d*, Figs. 2 and 3, in front of the cylinder, *a*, and so arranged that it can be swung to or from it at pleasure, or the stylus adjusted to any required delicacy. To the centre of the diaphragm is cemented a small piece of rubber tubing; against this rests a delicate spring, *e*, Fig. 3, permanently fixed at its lower end, having a sharp-pointed stylus in the other.

To operate the phonograph, the cylinder is smoothly covered with tin-foil. The crank then turned to the left, until the cylinder has

Fig. 2.

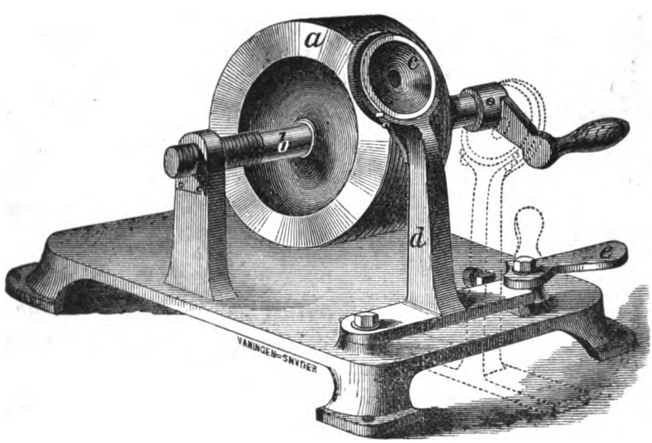
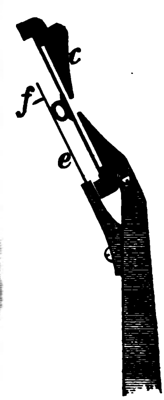


Fig. 3.



reached its limits. The stylus is now so adjusted, that when the cylinder is turned, it makes a slight depression in the foil directly over the groove.

By turning the crank, the whole length of the cylinder will pass in front of the stylus from right to left; the stylus having traversed the whole length of the groove. Any sound or speech made in the mouthpiece, *c*, while the cylinder is in motion, will be correctly recorded on the foil. The diaphragm will vibrate with the voice, and the soft and yielding foil will be marked along the line of the groove by a series of indentations, corresponding in every particular with the vibrations of the voice. Thus the yielding but inelastic foil re-

ceives and retains the mechanical impressions of the vibrations of the human voice with all their minuteness and subtle characteristics. These permanent impressions of the voice having been made, it is only necessary to remove the diaphragm, and turn the crank to the left until the cylinder is again in its normal position, when, by replacing the diaphragm, and placing in the mouthpiece a large funnel of paper to reinforce the sound, then turning the crank at the same speed as at first, we obtain from these impressions the aerial vibrations which made them.

FIG. 4.

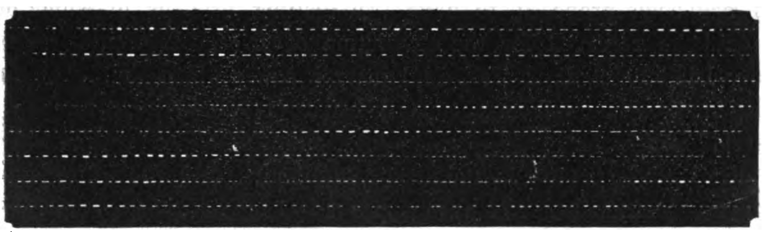


Fig. 4 represents a small section—magnified two diameters—of tin from the phonograph, called the matrix, containing a record of speech, by Henry Bentley, President of Phila. Local Tel. Co., March 23d, 1878, showing number and length of vibrations. The amplitude is not here shown, but would form a line of short and long curves, the curves varying with the force of the sound.

As an exact representation of sound is nothing more than a reproduction of similar acoustic vibrations in a given time, it is imperatively necessary that the cylinder revolve at a uniform speed and perfectly steady motion to obtain a faithful reproduction of the human voice.

French Narrow-Gauge Railways.—The railway from Commentry to Montluçon, with a gauge of one metre, carries 400,000 tons per annum. The Orleans company has built the road of Mondalazac, with a gauge of 1·10 m., for the transport of ores. The "Compagnie du Nord" has taken under its patronage a number of small companies; it guarantees bonds, makes advances, and aids by its advice. Among the companies thus aided and protected are the road from Hermes to Beaumont, 31 kilometres; from Marle to Rosoy, 28 kilom.; from Auvin to Fiéthun, 95 kilom.; all of 1 m. gauge.—*Ann. des Ponts et Chaussées.* C.

Water Supply of London.—In 1874 water was supplied to 3,655,000 lodgers, in 511,000 houses; the daily quantity of water was 526,612 cubic metres, or a little less than 144·96 litres per head. Eight companies, with a total capital of 281,218,500 francs, perform this service, paying average dividends of 6·3 per cent. In 1877 the number of inhabitants was 3,796,000, lodging in 533,000 houses; the daily consumption rose to 600,225 cubic metres, giving, for the summer months, a daily supply of 158·55 litres per head. A moderately heavy fire may require the concentration, on a given point, of about one-tenth of the whole supply, or a quantity of water sufficient, during the same time, for a city of 100,000 inhabitants. It has been proposed to have two distinct systems, of which one should be reserved for the extinction of fires. It would require only 135,000 cubic metres, a quantity which could probably be furnished by springs from the chalk-beds. It would be necessary to establish reservoirs at elevated points, and a new pipe system. The water department receives a subsidy of about 2,000,000 francs, or in the neighborhood of 574 francs per 1000 inhabitants. Paris, with 1,986,000 inhabitants, expends 2,500,000 francs, or about 1250 francs per 1000. New York, with a population of 1,098,000, expends 6,270,000 francs, or 5850 francs per 1000. Chicago, with a population of 550,000, expends 2,790,000 francs, or 5075 per 1000. —*Ann. des Ponts et Chaussées.* C.

Corrosion of Engines and Boilers by Fatty Acids.—In some steam-generators, especially in re-heaters, tubercular deposits are formed, clinging closely to the iron, which is commonly corroded at the point of contact as if by an acid. This brownish material has sometimes a greasy feel, and smells like burnt grease. Experiments, by Stingle, Wartha and Bolley, have shown that the deposit is due to the oxidation of the fatty lubricants. It may be prevented by neutralizing the fatty acid by some alkali. Milk of lime is the most economical, and quite effectual.—*Bull. de la Soc. Ind. de Mulhouse.* C.

Diffusion of Gases.—Sigmund v. Wroblewski has deduced the following general law: When a gas is absorbed, it diffuses itself through the absorbing body in the same way as heat spreads in a solid rod, whether the absorbing material is liquid, viscous, or solid. —*Ann. der Phys. u. Chem.* C.

Photo-Electricity.—The marked influence of sunlight on the electric conductivity of selenium, led Börnstein to experiment with other metals. He concluded that all bodies were affected by photo-electricity, but G. Hausemann, at the suggestion of Dr. Werner Siemens, entered upon investigations which appear to contradict Börnstein's views. Dr. L. A. Forssmann, of Stockholm, finds that even the selenium experiments do not seem to depend upon the influence of either the luminous, the thermal or the chemical rays; but upon waves of some other octave, or even, perhaps, upon longitudinal vibrations.—*Ann. der Phys. u. Chem.* C.

Metallurgy of Nickel.—M. Badoureau gives a complete essay on the treatment of nickel ores, in the *Annales des Mines*, vol. xii, pp. 237–340. C.

Study of the Ultra-Violet Solar Spectrum.—Angström limited his admirable memoir upon the Normal Spectrum of the Sun, to the visible portion. Cornu has extended it to the extreme limit which can be observed photographically, by the aid of a spectroscope, with objectives of quartz and a prism of Iceland spar. The limit thus attained is marked by the ray U, with a wave-length of 294·80. He has added two plates to Angström's atlas, of the same form and on the same scale.—*Comptes Rendus.* C.

Telephone Experiments.—From some observations by A. Demoget, of Nantes, we select the following: It is desirable that the plates should vibrate in unison with the sounds which are transmitted. The voices of women and children are best heard with plates of 3 to 5 centimetres' diameter; those of men, with plates of 6 to 8 centimetres. If the gamut is sung in a telephone with a large disc, the first low notes will be easily heard, while the highest notes will be less distinct; if the disc is small, the highest notes will be most clearly heard. At one end of a line two telephones may be placed in double circuit, and if two persons sing simultaneously in the two instruments, the two voices will be heard in a single telephone at the other end of the line. M. Demoget proposes to experiment with two or three telephones of different pitch, in a sort of acoustic horn, in the hope of getting more intense and more distinct sounds.—*Les Mondes.* C.

New Cooling Agent.—Ch. Tellier has used trimethylamine for the production of cold, under conditions which lead him to regard it as the best known frigorific. Vaporizing at + 8° C., under ordinary pressures, it requires a pressure of only from one to two additional atmospheres to reliquefy it. This property allows us to utilize waste heat, especially the waste steam of manufactories, so that the cost of the refrigeration is limited to the bare expense of superintendence. A degree of cold equivalent to that produced by the consumption of 10,000 kilogrammes of ice, can thus be obtained for a few francs.—*Les Mondes.* C.

Hydrogenium.—Fifty years ago, Dumas announced his belief that hydrogen was a vaporized metal. At first he found few to agree with him, but subsequent experiments, by different chemists, led many to admit the probable existence of a metal called *hydrogenium.* The recent experiments of Cailletet and Pictet exhibited minute crystals, confirming this view. Dumas thinks this confirmation may be of great practical industrial importance. "The positive knowledge of the metallic nature of hydrogen would have an important influence in metallurgy; industry would reap the benefit of it;" and on these accounts the late experiments should excite a lively interest among the friends of labor, as well as among devotees of science.—*Soc. d'Enc. pour l'Ind. Nat.* C.

Telephone Relays.—DuMoncel, in speaking of recent experiments by Pollard and Garnier, suggests the use of a telephone which should be both receiver and transmitter. Its local battery might act as a relay by the intervention of the induction coil, thus increasing the sounds and transmitting them to great distances.—*Comptes Rendus.* C.

Parisian Scientific Conferences.—The French Scientific Association has organized a series of conferences, to be held at the Sorbonne. Their object is to make known and explain new inventions and discoveries. Their programme embraces repetitions of Cailletet's experiments on liquefaction and solidification of gases; explanations by H. Ste.-Claire Deville; a discourse by Dumas, on the history of the association and its services to science; and other interesting features. Dumas proposes that the association should open a subscription for a monument to its founder, Le Verrier.—*Les Mondes.* C.

New System of Pile-Driving.—Messrs. Stoecklin and Vetillart, in their works for enlarging the harbor of Calais, found great difficulty in sinking the piles and plankings through the fine, moist beach-sand. The use of water to facilitate the penetration of broken iron piles, suggested its use on the outside and in advance of the wooden logs that they were using. By the help of two hand-pumps the sand was so loosened and held in suspension, the labor was greatly abridged. On the old plan, an average of 185 blows was required to drive a pile, 900 blows for a panel, requiring, on an average, 8 hours 36 minutes. With the help of water injection, the number of blows per panel varied from 0 to 50, the mean time being only 1 hour 9 minutes; many of the panels required only from 14 to 16 minutes, and the longest time was only 1 hour 45 minutes. The extraction of displaced or broken piles or planking, which has hitherto been attended with great difficulty, is accomplished with the greatest ease by the new system.—*Ann. des Ponts et Chaussées.* C.

Connection of Electro-Magnetic Rotation with Uni-Polar Induction.—Edlund has studied the currents which are generated by the rotation of a cylindrical magnet, surrounded by a metallic mantle which can be turned on the same axis. Letting $s_1 =$ strength of current generated by rotation of the mantle, $k =$ a constant depending on the condition of the mantle and the position of the points where the conductor touches the mantle, $M =$ magnetic movement of the magnet, $w =$ angle described in unit of time, and $l =$ resistance of conducting wire, he finds $s_1 = \frac{k M w}{l}$. He explains the several results obtained by various rotations of the magnet and mantle, in accordance with his general hypotheses, by accumulations of æther at various points.—*Ann. der Phys. u. Chem.* C.

Loss of Power in Steam Engines.—J. Illeck publishes in the *Journal of the Austrian Association of Engineers and Architects*, a discussion of the loss of efficiency in consequence of some of the principal sources of waste and condensation in steam engines. C.

Aluminium Telegraph Wires.—Aluminium has been recommended as a coating of telegraph wires, because its electric conductivity is about twice as great as that of iron.—*Berg- u. Hütten-Zeitung.* C.

The Douro Bridge.—The Northern Portuguese Railway has lately completed a fine work of engineering skill, in a bridge over the Douro, at a point where its breadth is 140 metres, and its depth 18 metres. The bed is sand and mud, with a thickness varying from 15 to 56 metres. The river is subject to great and rapid freshets, which sometimes raise the surface 12 or 13 metres in 24 hours. The railway reached the bank of the stream at a height of 60 metres above the low water level, and at this height the distance between the banks was 350 metres. The construction of a viaduct, under the circumstances, presented serious difficulties. Plans were presented by four firms, and the one offered by G. Eiffel & Cie., of Paris, was adopted. It was impossible to think of building a pier in the river; it was therefore spanned by a single iron arch, of 160 metres spring, a little larger than the central span of the St. Louis bridge. The arch abuts against piers of masonry on each bank; there are two other piers on one side, and one on the other, at distances varying from 29 to 37 metres. The central arch is crescent-shaped, formed by two parabolas, intersecting at the abutments and having a height of 10 metres at the summit. It is composed of two principals, hinged at the abutments, so as to allow for changes of temperature; at starting they are 15 metres apart, but the distance is reduced to 4 metres at the summit. This arrangement was made in order to secure effective resistance to the violent winds which are frequent in the valley, and all the trellis-work, both of the roadway and of the piers, was planned for the same purpose. The mounting of the arch presented great difficulties, on account of the impossibility of erecting scaffolding, but by the help of steel cables, crossing the river at the level of the platform, the two halves, simultaneously constructed, met at the key with absolute precision.—*Ann. des Ponts et Chaussées.* C.

Estimation of Sound-Velocity by the Method of Coincidences.—Akos Szathmari has modified König's method, by substituting a pendulum current breaker for the tuning-fork. He finds a velocity, in dry air at 0° C., of 331·57 metres, which is nearly an arithmetical mean between the results obtained by Regnault (330·7) and by Moll and Van Beck (332·26). He claims as advantages for his method, the ease with which it can be employed, and the fact that it requires only a small space, in which the temperature and moisture of the air are uniform.—*Ann. der Phys. u. Chem.* C.

Disaggregation of Tin.—Organ-pipes, after long use, become brittle and fall to pieces. Oudemans stated (*Chem. Jahresber.*, 1872, p. 256) that plates of pure tin, which contain, at most, 0·3 per cent. of lead and iron, break into small fragments, like molybdenum-sulphide, in the railway transport from Rotterdam to Moscow, in severe cold weather. A similar phenomenon has been lately observed at the Royal Pyrotechnic Laboratory in Spandau. A large quantity of tin plates (295 kilogs.) became exfoliated and crumbled into small particles. Still later, larger quantities of Billeton block tin (1950 kilogs.) were similarly affected. The warehouses were thoroughly dry; the tin contained only traces of foreign metals, no sulphur or phosphorus, and no tin-oxide. According to Dr. Petri's account, the tin could be pulverized more easily than ordinary tin filings, and gave out hydrogen more quickly with acid. While it was in the warehouse there was no severe cold, yet the disaggregation went on.—*Ann. der Phys. u. Chem.* C.

A New Sense.—M. E. Cyon has sent a note to the French Academy, in which he claims that the eighth pair of cerebral nerves contains two nerves of entirely distinct senses—the auditory nerve, and the nerve of space (*Raumnerv*). He regards the latter as the source of all our ideas of extension, and of the three dimensions of space. C.

Electro-Motive Force of Water in Capillary Tubes.—Dr. H. Haga publishes the following results of his investigations upon the electro-motive force which is generated by the flow of water in capillary tubes. The potential difference is proportional to the pressure; it is independent of the length of the tubes; it is modified by the nature of the inner wall of the tube; it increased with the resistance of the water; it probably increases with the temperature. J. W. Clark finds that: 1. The narrower the tube, the greater is the force. 2. In very fine tubes, the force is independent of the length; in larger tubes it diminishes with the length. 3. Covering the inner wall with different substances, the force varies, as Quincke ascertained. 4. The force diminishes with time, whether the water is flowing or at rest; the original force may be restored by cleansing the tubes with sulphuric acid and distilled water. 5. The seat of the force is in the bounding area of the water and the tube.—*Ann. der Phys. u. Chem.*
C.

On Some Physical Points connected with the Telephone.[1] —This instrument may be employed both as a source of a new kind of current and as the detector of currents which are incapable of influencing the galvanometer. It shows that the form and duration of Faraday's magneto-electric currents are dependent on the rate and duration of motion of the lines of force producing them, and that the currents produced by the alteration of a magnetic field vary in strength with the rate of alteration of that field; and further, that the infinitely small and possibly only molecular movement of the iron plate is sufficient to occasion the requisite motion of the lines of force. He pointed out that the telephone explodes the notion that iron takes time to be magnetized and de-magnetized. Mr. R. S. Brough has calculated that the strongest current employed in a telephone is $\frac{1}{1000000000}$ of the CGS unit. Mr. Preece explained that the dimensions of the coil and plate depend on the strength of the magnet, but the former should always consist of fine wire and be made as flat and thin as possible. The adjustment of the position of the magnet (as near as possible to the plate without touching) is easily effected by sounding a vowel sound *ah* or *o* clearly and loudly; a jar is heard when they are too near together. After briefly enumerating the attempts which have been made to improve the instrument, he mentioned the various purposes to which it can be applied. In addition to being useful to the lecture room in conjunction with several well-known forms of apparatus, it forms an excellent detector in a Wheatstone bridge for testing short lengths of wire, and condensers can be adjusted by its means with great accuracy. M. Niaudet has shown, by employing a doubly wound coil, that it can be used to detect currents from doubtful sources of electricity, and it is excellent as a means of testing leaky insulators. Among the facts already proved by the telephone, may be mentioned the existence of currents due to induction in wires contiguous to wires carrying currents, even when these are near each other for only a short distance. Mr. Preece finds that if the telephone wire be enclosed in a conducting sheath which is in connection with the earth, all effects of electric induction are avoided; and, further, if the sheath be of iron, magnetic induc-

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[1] From a Paper read by Mr. W. H. Preece before the Physical Society, January 19th, 1878.

tion also is avoided, and the telephone acts perfectly. A great number of experiments on the use of the instrument on telegraphic lines were then described, from which it appears that conversation can be carried on through 100 miles of submarine cable, or 200 miles of a single wire, without difficulty, with the instrument as now constructed. The leakage occurring on pole-lines is fatal to its use in wet weather for distances beyond five miles. An interesting series of telephones was exhibited, and, by means of one of very large dimensions, Mr. Preece showed that the current produced by pressing the centre of the plate sensibly affects a Thomson galvanometer, and that the motion of the needle ceases in a remarkably instantaneous manner, as soon as the pressure is removed, a necessary condition, in order that the receiving-plate should accurately reproduce the motions of the sending-plate.—*Chemical News.* *

Liquefaction of Gases.—M. Tissandier points out that M. Cailletet's experiments fully confirm the theory, first put forward by Andrews, that there exists for the permanent gases a critical point of pressure and temperature, above which they cannot be reduced to a liquid condition. It is found for each gas that a certain pressure has to be combined with a certain lowering of temperature. Either cold or pressure, separately employed, gives no result, even at great degrees of intensity. It is perhaps owing to their not having been subjected to a sufficiently energetic joint action of these agents that the permanent gases were able to retain their intractable independence hitherto, in spite of the attacks made on their freedom. M. Berthelot himself has experimented with pressures up to 800 atmospheres and cold down to — 100° C. M. Cailletet found that binoxide of nitrogen retained its gaseous form at the pressure of 270 atmospheres and the temperature of + 8°. But combining the points critical for marsh-gas—180 atmospheres and + 7°—it was liquefied. The same experimenter finds that atmospheric air, dried and freed from carbonic acid, is converted, when at a pressure of 310 atmospheres, into a true hoar frost, while at a pressure of 200 atmospheres the appearances on the inside of the tube were similar to those occasioned by the trickling down of a subtle fluid like ether. At 255 atmospheres the threads of fluid were much more visible.—*Iron.*

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Solar Photography.—M. Janssen is acquiring new and valuable knowledge relative to the structure of the sun's disc, by means of large images and brief photographic exposures. He is thus enabled to neutralize the effects of irradiation. By means of a special and very perfect mechanism, he has reduced the time of exposure to $\frac{1}{3000}$ of a second, obtaining sharply-defined images corresponding to discs of more than a metre in diameter.—*Comptes Rendus.* C.

Fall of the Western Approach to South Street Bridge.—At a quarter after seven o'clock on the morning of February 10th, the western approach to the South Street Bridge, 420 ft. in length by 55 ft. in width, and consisting of nine masonry arches, fell into the marsh a complete wreck. About three months before a slight settlement of the second pier from the western end of the structure was observed, but no cracks being found, no immediate serious danger was apprehended.

The necessity for taking immediate steps for the preservation and repairs soon became apparent, and on the morning in question a gang of men were at work shoring up, when suddenly the pier sank rapidly at its northern end, and almost immediately fell, carrying with it the two arches resting upon it. This removing the resistance to the thrust of the remaining arches, they fell also.

The structure consisted of nine segmental arches of 43½ ft. clear span and 14 ft. rise, resting on piers 5½ ft. thick, 13½ ft. high, by 55 ft. long. The piers, in turn, rested on foundations consisting of 84 piles, averaging 10 ins. diameter, placed 3 ft. apart. The piles were cut off 2 ft. below low water mark, and the earth excavated 2½ ft. below this, and the cavity filled with concrete. On top of, and ragbolted to, the piles, was a double course of 8 in. by 8 in. grillage, the interstices of which were also filled with concrete; over this was a platform 10 ft. by 60 ft., consisting of two courses of 3 in. hemlock plank, placed diagonally and spiked to the grillage.

Mr. D. McN. Stauffer, engineer in charge of the construction, states that "each and every pile under the structure had four final blows applied from the 2000 pounds hammer, and the full height of the drop (36 ft.), and if it did not descend more than 1 in. in these four blows, it was considered home." He also states that the piles under the pier which failed, were driven to a depth of 19 ft., where they encountered a hard stratum believed to be gravel.

Many causes have been assigned for the failure of the structure, after standing for nearly eight years, but it must be confessed that none of them are entirely satisfactory, nor is the true cause likely to be ascertained until a thorough examination is made, probably involving an excavation or boring to the bed-rock.

The cause assigned by Mr. Stauffer, is that "the tremor produced in the piles, by travel on the bridge, would loosen them sufficiently to allow the percolation of water down their sides, and finally throw the entire weight on the toes of the piles, and if the gravel on which they rested was merely a thin bed or pocket, the water probably softened it, allowing the piles at the north end of the pier to drop through to the mud."

In a paper read before the Engineers' Club, Prof. Haupt, from data obtained from the drawings in the office of the chief engineer and surveyor, estimated the pressure placed upon each of the piles to have been a little more than 36 tons, and says: "As the piles * * * were driven through, or into, soft mud inundated at every tide, * * * it is evident that there could have been very little lateral support from that source; and hence the pressure placed upon them, and so nearly equal to that which the same number and size of piles would support when driven in a compact soil, was in excess of their bearing power, and the cause of the fall of the structure."

Since the above was written, Chief Engineer Smedley has furnished the following information on the subject:

"Levels taken six days prior to Feb. 10th, did not show any appreciable difference from those taken three days before; but from the 5th to the 8th the settlement per day increased from ·03 ft. to ·07 ft. On the afternoon before the fall it sank from ·02 ft. to ·03 ft. per hour. The last 24 hours amounted to ·6 of a foot, when it settled, nearly vertical, 17 ft. at the north end, and 7·5 ft. at the south end. The whole surface of the meadow, within 20 ft. of the debris, was raised about 4 ft.

"The soundings have since been taken to rock, which was reached at 28·4 ft. below low tide, at the south end of pier, and 31·1 ft. at the north end. At 30 ft. north of the bridge, the rock was found at 25·4 ft.

"The whole of the sounding was through stiff muck, except a stratum, of about 2 ft. thickness, mixed with sand, which was somewhat harder, and found in each case at 17·1 ft."

It would, therefore, seem probable that the piles had rested on this stratum of gravel, which is supported on soft material, as shown by the soundings, and that the frictional support being destroyed by the action of the tides and tremor of the structure, the piles pierced or broke up the gravel stratum. The mass once in motion, its momentum would be sufficient to crush the piles, even if the slope of the rock had been sufficiently flat to hold them at their toes. *

Launch of the City of Rio de Janeiro.—The largest iron steamship ever built at Chester, with two exceptions, the Peking and Tokio, was successfully launched from Roach & Sons' yard, on March 6th, at half-past two o'clock P. M. The first frame was raised on the fifth day of November, 1877, and therefore but four months and one day were consumed in her construction. The new vessel was christened the City of Rio de Janeiro, and is the first of four steamships being constructed by the Messrs. Roach for passenger and freight traffic between New York and Brazil. Everything about her is of American manufacture.

The Rio de Janeiro is 370 feet long over all, 39 feet beam. Depth of hold from base line to top of spar deck is 31 feet 6 inches, and she will be of three thousand and five hundred tons, custom house register. She has three decks beside the hurricane deck. The spar, main and hurricane decks are entirely of iron. All the deck frames and the deck houses are also of iron.

The machinery proper consists of two compound surface condensing engines of 2500 horse power, and with separate engines for working the air and circulating pumps. The propeller is of brass, of the Hirsch patent, having four blades, and it is 16 feet in diameter.

She will be barquentine rigged; the lower masts, being iron, will be used as ventilators. The dining saloon is one hundred and thirty feet long by forty feet broad in the widest part. From the dining saloon is a spacious staircase leading up to a large and elegant social hall fitted with rare hard woods. In this hall there will be fourteen elegant staterooms, fitted with sofas, washstands, and with berths, arranged for one or two persons; the upper berths rolling back in the same manner as those used in the Pullman palace cars.

The maximum passenger capacity will be for one hundred first class passengers, and four hundred persons in the steerage.

She will be provided with eight metallic life-boats, the carrying capacity of which will be from 35 to 60 persons each, and with four life-rafts, which, altogether, will carry 700 persons.

The Rio de Janeiro was built under the special supervision of the French Bureau Veritas, and the American Ship-Masters' Association, of New York, and will have the highest rate. *

Book Notices.

ENGINEERING SPECIFICATIONS AND CONTRACTS. By Louis M. Haupt, C.E. 8vo., pp. 300. Philadelphia, J. M. Stoddart & Co. 1878.

Defective specifications often result in loss of time and money, in the erection of works, to an extent equally disastrous, from a financial point of view at least, as defective designs, and it is, therefore, very important that engineers should be able to prepare those papers in the best possible manner.

It is true that in most of the offices of our older engineers, are to be found files of such documents, which have done excellent duty, and serve as models to those having access to them. A large proportion of our young engineers, however, have not such resources to fall back upon, and even if they had, have not the experience or knowledge necessary to select the best; moreover, the student of engineering should be made familiar with the preparation of such papers, not only for the value of such knowledge in his future practice, but to give him a better conception of such problems as may be given him, illustrative of the studies he is pursuing.

A work covering this ground has been needed, and to supply this want the author was prompted to prepare this one, and which he has done with excellent judgment.

The preparation of "contracts" more properly belongs to the legal profession, but it is important that the engineer should be consulted in connection therewith, that there may be no ambiguity as to the intention of the parties thereto upon any of the engineering features; that portion of the book devoted to this subject is, therefore, quite appropriate.

The work is divided into six chapters, and at the end of each is a series of questions relating to its contents, adding to its value as a text book, while copious marginal notes facilitate references.

The two subjects mentioned comprise Chapters III and VI, covering 150 and 40 pages respectively, and contain well selected examples of documents prepared, for the most part, for works now completed.

Chapter I contains a concise statement of what is required in good drawings, intended to form the basis of contracts.

Chapter II, on estimates and measurements, besides other important matter, gives the rules of the Carpenters' Co. of Philadelphia, for measuring carpenters' and joiners' work.

The facts and forms contained in Chapter IV, relating to advertisements, and Chapter V, on bids or proposals, and the glossary of technical terms in the appendix, will be found very useful. *

A HANDBOOK OF VOLUMETRIC ANALYSIS. Designed for the use of students in colleges and technical schools. By Edward Hart, S. B., Fellow of Chemistry, in the Johns Hospital University, Baltimore. John Wiley & Sons, N. Y. Price, $2.50.

Chemical analysis has become a branch of modern education so important, that good text books for students, embracing the essential features of the science, with the improved processes of recent investigators, are not more numerous than the demand.

From the greater rapidity with which results can be obtained by *volumetric* analysis, it will always commend itself to those engaged in technical work.

In the present volume the author has given so much of the work of Dr. Mohr as has stood the test of experience, and brings the subject up to the present time, in a condensed form. To the foreign literature on the subject, is added some practical information derived from American chemists, whose opportunities render their observations valuable. As a handbook for students, and to those engaged in technical analysis, the book will be of value. B.

PROCEEDINGS OF SOCIETIES.

The American Institute of Mining Engineers held its February meeting for this year, in Philadelphia. The first session was held at the rooms of the American Philosophical Society, February 26th, at 8 o'clock P. M.

The President, Prof. T. Sterry Hunt, presented the opening address, upon "The Earth's Atmospheric Envelope during the Carboniferous Age;" and the following papers were read:

"The Manufacture of Artificial Fuel at Port Richmond," by Mr. E. F. Loiseau.

"The Economy Effected by the Use of Red Charcoal," by Mr. Bernard Fernon.

A note on "Manganese Pig-Iron," by Dr. R. W. Raymond.

The second session was held at the Franklin Institute, on Wednesday, at 10 A. M. Dr. T. M. Drown read a paper on "Pulverized Zinc, and its Uses in Analytical Chemistry;" and Prof. J. S. Smock, on "The Fire Clays and Associated Plastic Clays, Kaolins, Feldspars and Fire Sands of New Jersey."

A note, by Mr. P. Barnes, on "The so-called Blue Process of Copying Tracings," was also read.

The third session was held at the Academy of Natural Sciences, on the afternoon of Wednesday, when the following papers were read:

"The Nickel Ores of Oxford, Quebec, Canada," by Mr. E. C. Eustis.

Note on "The Drainage of a Flooded Ore Pit, at Pine Grove, Pennsylvania," by J. Birkinbine.

"The Strength of Wrought Iron, as affected by its Composition and by its Reduction in Rolling," by A. L. Halley.

"An Improved Tripod for Surveying Instruments," by J. H. Harden.

"A Suspended Signal for Surveying," by Prof. H. S. Munro.

The closing session was held at Memorial Hall, Centennial Grounds, on Thursday morning.

Papers were read on "Some New Points in the Geology of Lancaster Co., Pennsylvania," by Prof. Persifor Frazer, Jr.

"Red Charcoal in the Blast Furnace," by Wm. Kent.

"Some Minerals from Sterling Hill," by Professor S. G. Koenig.

Note on "The Cost of Construction of the Converting Works of the Edgar Thomson Steel Co., of Pittsburg, Pennsylvania," by P. Barnes.

"Index of the Geological Reports of the Various States and Territories," by Prof. F. Paine, Jr.

"The Late Workings of the Mariposea Estate," by Charles M. Roelker.

"A Filter for Boiler Water," by P. Barnes.

"Memoranda showing the Percentage of the different Expense Accounts in Mining Hematite Ore at Manhattan Mine, Sharon Station, N. Y.," by J. F. Lewis.

Engineers' Club of Philadelphia.—At the meeting of the club held Feb. 16th, Mr. Charles A. Ashburner read a paper[1] on the "Oil Sands of Pennsylvania," in which he gave an outline of their distribution over the State, together with their geological position, character, etc.

The percentage of risk of obtaining "dry holes," which the producers experienced in the different districts, was referred to, and the statement made that the risk is greater in the southern and western districts and least in the northern—it being only about three per cent. in the latter. Specimens of the sands and crude oils exhibited, added to the interest in the paper.

Mr. Geo. H. Christian followed with a paper on the "Lowe Gas Process," giving a description of the apparatus, and the chemical changes which the material undergoes in the course of manufacture, together with an estimate of the first cost and maintenance of the plant. The paper was illustrated by a large sectional drawing and a general view of the new gas-works at Lancaster, Pennsylvania.

At the meeting held March 2d, twenty-two members were present.

Mr. Rudolph Herring read a paper on the "Sewerage of Philadelphia," in which he gave an outline of our system of house and street drainage, and he pointed out "some of the defects, together with their remedies, which, if not securing a complete immunity from disease, would remove a powerful agency for evil," and concludes that "the whole subject, especially the house drainage, needs sincere and early attention and study. But more than that, it needs *action.*"

A paper by Prof. L. M. Haupt, on the "South Street Bridge," was next read. From data obtained from the office of the City Engineer, he estimates the pressure on the piles forming the foundations for the piers of the western approach to be about 36 tons to each pile having an average diameter of 10 inches. These piles "were driven through and into a soft mud inundated at every tide; the pressure placed upon them was in excess of their bearing power in such soil, and the cause of the fall of the structure."

Mr. Geo. Burnham gave a general description of the masonry work of the bridge, and presented a plan which he believed could have saved a portion of it. The subject was discussed by a large number of members.

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[1] See page 225, this volume.

Franklin Institute.

Hall of the Institute, March 20th, 1878.

The stated meeting was called to order at 8 o'clock P. M., the President, Dr. R. E. Rogers, in the chair.

The attendance of members and visitors was very large, filling the lecture room to its utmost capacity; the number estimated at 375.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 10 persons were elected members of the Institute; the following donations to the Library were reported:

Maps of the Battle-field of Gettysburg, in three sheets. From Chief of Engineers.

Specifications and Drawings of Patents for August and September, 1877. From U. S. Patent Office.

Annual Report of the Board of Regents of the Smithsonian Institution, for 1876. From the Institution.

Papers relating to Foreign relations of the United States, for 1877. From Secretary of State.

Progress and Resources of New South Wales. By Chas. Robinson. Sydney, 1877.

Journal and Proceedings of the Royal Society of New South Wales, 1876. Vol. 10. Sydney, 1877.

Railways of New South Wales. Report by John Rae. From 1870—1875, incl. Sydney, 1876.

Annual Report of the Department of Mines, New South Wales, for 1876. Sydney, 1877.

Climate of New South Wales. By H. C. Russell. Sydney, 1877.

Kamilaroi, and other Australian languages. By Rev. W. Ridley. 1875. From Royal Society, New South Wales.

Fifth Annual Message of the Mayor of Philadelphia. 1877. From the Mayor.

Annual report of the Light House Board, for 1877. From the Board.

Geological Survey of New Jersey. Report on the Clay Deposits. Trenton, 1878. From the State Geologist.

Annual report of the Secretary of the Navy, for 1877. From the Secretary.

Annual reports of the Adjutant General of Pennsylvania, for 1862, 1867, 1869, 1870, 1874, to 1877, incl. From the Adjutant General.

Second and Fourth Annual reports of the Commissioners of Fairmount Park, 1870 and 1872. From the Commissioners.

Instructions for observing the transit of Mercury, 1878, May 5th and 6th. U. S. N. Observatory. From the Observatory.

List of surviving members of the American Philosophical Society at Philadelphia, 1878. From the Society.

Report of the Director of the Meteorological Observatory, City of New York, for 1871. From the Director.

Twenty-fifth Annual report of the President, Treasurer and Librarian of the Mercantile Library Association, of San Francisco, 1877. From the Librarian.

Annual reports of the American Iron and Steel Association, for 1874, 1875 and 1876. From the Association.

Proposed substitution of the Metric for our own system of weights and measures. By Persifor Frazer, Jr. From the Author.

Decisions of the Commissioner of Patents and U. S. Court, for 1877. From the U. S. Patent Office.

Pennsylvania Magazine of history and biography. Vol. I. 1877. From the Historical Society.

The Secretary reported that at the last meeting of the Committee on Science and the Arts, a report was adopted, recommending the award of the Scott Legacy Premium to the Pratt & Whitney Co., of Hartford, Conn., for their gauges, taps and dies.

Mr. W. B. LeVan presented an illustrated description of an accident to a hydraulic elevator at the Grand Hotel, Paris, France.

The Secretary's report embraced Edison's Carbon Telephone Transmitter; Edison's Phonograph; Byrne's Cautery Battery; Bonwill's Dental Engine; Grey's Bi-Polar Telephone; and the American Burglar Alarm.

Action on the amendment to Art. XVI of the By-Laws, proposed at the last meeting, was postponed to the stated meeting in April next.

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary.*

May 6

VOL. CV.] [NO. 629.

THE JOURNAL OF THE FRANKLIN INSTITUTE

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS.

PUBLISHED BY THE INSTITUTE,

Under the Direction of the Committee on Publication.

Third Series.] MAY, 1878. [Vol. lxxv, No. 5.

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ITEMS.

Philadelphia; FRANKLIN INSTITUTE, 15 South Seventh St.

JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CV.	MAY, 1878.	No. 5.

THE Franklin Institute is not responsible, as a body, for the statements and opinions advanced by contributors to the JOURNAL.

REPORT OF THE COMMITTEE ON DYNAMO-ELECTRIC MACHINES.

The Board of Managers of the Franklin Institute having empowered its Committee on Instruction to purchase a Dynamo-Electric Machine, it was deemed advisable to examine into the merits of, and to test, the various machines offered for sale. This was undertaken partly as a guide in making a selection for purchase, and also to obtain reliable data regarding the adaptability of such machines to the production of Light.

In view of the scientific importance of the work, the Committee on Instruction, which consists of five members of the Board of Managers, availed themselves of the services of four other members of the same, who, by request, assisted in the investigation, and now join in this report.

The work was divided among Sub-Committees as follows:

On Photometric Measurements, Messrs. Briggs, Profs. Rogers and Chase. On Electric Measurements, Profs. Houston, Thomson, and Mr. Rand. (Mr. Rand's business engagements prevented his taking active part in the work of this sub-committee.) On Dynamical Measurements, Messrs. Jones, Sartain and Knight.

Previous to the commencement of the labors of the Committee, an invitation was extended to makers of dynamo-electric machines, with a request that they should furnish machines for competitive trial. This invitation was also given in the columns of the JOURNAL of the Institute, and received general publication in the newspapers and scientific periodicals. Especial requests were addressed to M. Breguet, of Paris, France, maker of the "Gramme" machine; to Messrs. Siemens Bros., of London, Eng., makers of the "Siemens" machine; to Messrs. Condit, Hanson & Van Winkle, of Newark, N. J., makers of the "Weston" machine; to the Telegraph Supply Co., of Cleveland, Ohio, makers of the "Brush" machine; and to Messrs. Wallace & Sons, of Ansonia, Conn., makers of the "Wallace-Farmer" machine.

The only machines supplied directly from the makers were two each of the Brush and Wallace-Farmer types, but the Committee were gratified in obtaining, through the courtesy of Prof. H. W. Wiley, of Purdue University, Lafayette, Ind., a "Gramme" machine. This Gramme machine formed a part of the exhibit of M. Breguet at the Centennial exhibition, and, for this and other reasons, is believed to be a good example of its class.

The apparatus employed by the sub-committee on electrical measurements, in their determinations, were kindly loaned, for the purpose, by the Committee on the Central High School of Philadelphia, and are from the large and valuable cabinet of philosophical apparatus of that institution.

The apparatus used to measure the power required to drive the electric machine, was a Brown Dynamometer, loaned by the Fales & Jenks Manufacturing Co., of Providence, R. I.

Mr. J. W. Sutton, of N. Y., also loaned us a spring dynamometer, which is a very compact instrument, and possesses peculiar advantages for use in many locations. The circumstances, however, under which our tests were made, rendered this less available, and it was, therefore, not used.

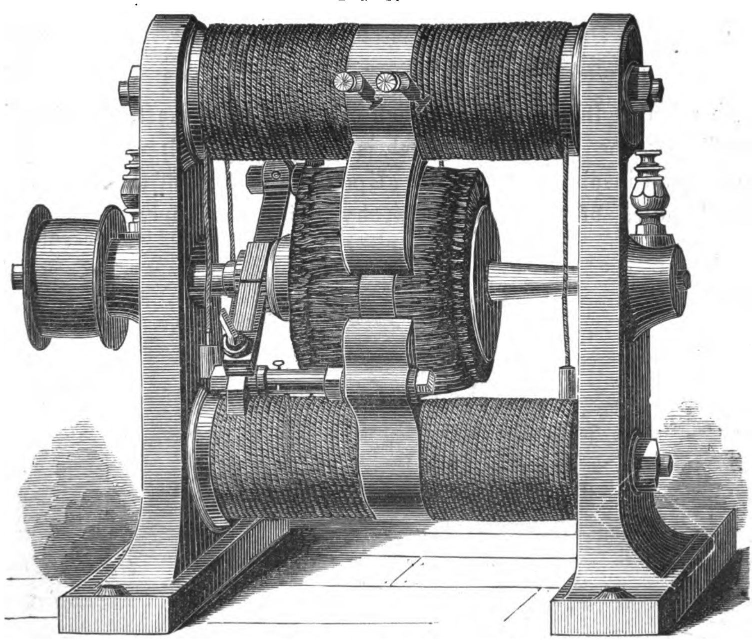
The source of power for the experiments was an upright steam-engine belonging to the Institute. It has 6″ bore of cylinder, and 8″ stroke, heavy fly-wheel 30″ diameter, and governor so adjusted as to give speeds from 100 to 250 revolutions per minute.

In measuring the power used, indicator diagrams were taken from the engine, as a check on the dynamometer readings, although the

latter were relied upon in making our calculations, except in the case of the large Wallace machine. This machine requiring more power than could be supplied by the Institute's engine, or safely transmitted by the dynamometer, it was taken to the works of the I. P. Morris Co., and driven by an engine of 9″ bore and 18″ stroke, and the amount of "power consumed" determined from the indicator diagrams. This determination was sufficient to demonstrate the fact that this machine possesses no economical advantages over the smaller one of the same make, but the "power consumed" is omitted from the table of results, as comparisons based on the different methods would be obviously unsatisfactory.

The following is a description of the machines submitted to examination. Their dimensions are given in Table I:

Fig. 1.



The Gramme machine, Fig. 1, consists of two cylindrical electro-magnets, with their combined poles extended by pieces of such shape as nearly to envelop the armature which rotates between them, Figs. 2 and 3. The armature is composed of a ring of soft iron, with insulated copper wire wound over its entire surface. This wire is divided into sixty coils connected successively at their ends, and the loops thus formed between each pair of coils are connected to the

copper strips of the commutator. Fig. 2 represents the mode of winding this wire on the ring, only a few turns, however, being shown.

The commutator consists of copper strips equal in number to the armature coils, placed radially edgewise around the shaft of the

Fig. 2.

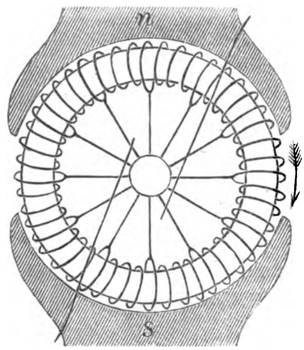
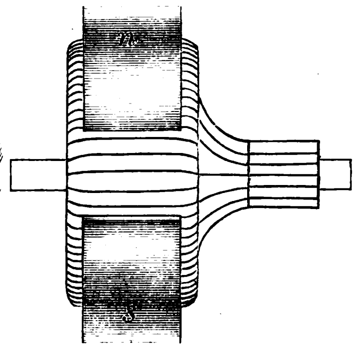
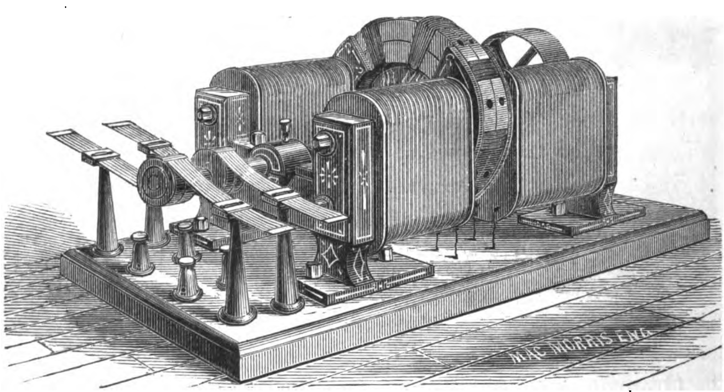


Fig. 3.



machine, and insulated from each other and the shaft, thus forming a cylinder, the surface of which is composed of alternate strips of copper and insulating material. Upon the surface of the commutator rest bundles of soft iron wire, by which the currents generated

Fig. 4.



in the armature coils are conducted to the external circuit. As the armature is rotated between the poles of the field magnets, currents of electricity are generated.

These machines are also constructed with two commutators, each connected respectively to alternate armature coils, in which case the

external circuit can be divided; but it is usual to pass both currents through the field coils, and then join them in the external circuit. This machine runs smoothly and very quietly, with few or no sparks at the commutator, and very little heating, the temperature of the armature being about 98° Fahr. after running nearly five hours.

The Brush machine, Fig. 4, has, for its magnetic field, two horse-shoe electro-magnets, with their like poles facing each other, at a suitable distance apart, the circular armature rotating between them. In this machine the currents are generated in coils of copper wire, wound upon an iron ring, constituting the armature. This ring is not entirely covered by the coils, as in the Gramme armature, but the alternate uncovered spaces between the coils are almost completely filled by iron extensions from the ring, thus exposing large surfaces of the armature ring for the dissipation of heat, due to its constantly changing magnetism, as in the Pacinotti machine.

Fig. 5.

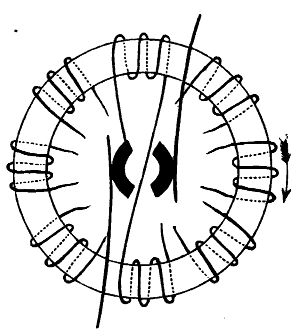
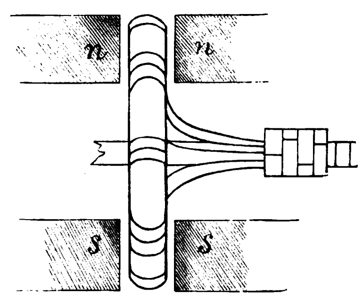


Fig. 6.



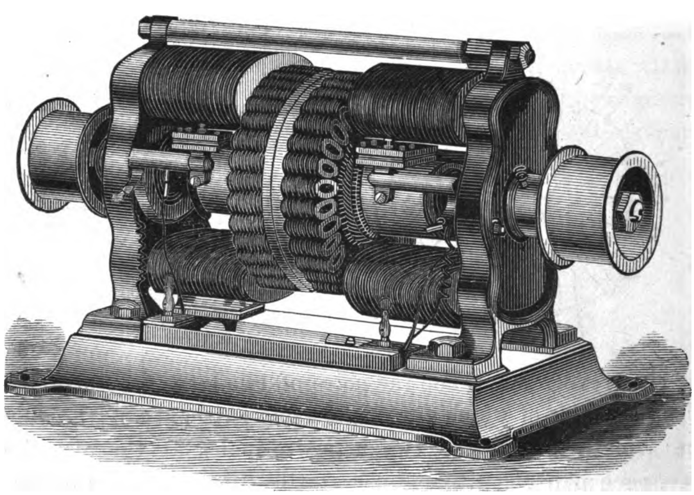
The ring revolves between the poles of two large field magnets, the two positive poles of which are at the same extremity of the diameter of the armature, and the two negative poles at the opposite extremity, each pair constituting practically extended poles of opposite character.

The coils on the armature ring are eight in number, opposite ones being connected end to end, and the terminals carried out to the commutator. Figs. 5 and 6 show this arrangement, only one pair of coils, however, being shown in Fig. 5 as connected. In order to place the commutator in a convenient position, the terminal wires are carried through the centre of the shaft, to a point outside the bearings.

The commutators are so arranged, that, at any instant, three pairs of coils are interposed in the circuit of the machine, working, as it were, in multiple arc, the remaining pair being cut out at the neutral point; while in the Gramme machine, the numerous armature coils being connected end to end throughout, and connections being made to the metal strips composing the commutator, two sets of coils in multiple arc are at one time interposed in the circuit, each set constituting one-half of the coils on the armature.

The commutator consists of segments of brass, secured to a ring of non-conducting material, carried on the shaft. These segments are divided into two thicknesses, the inner being permanently secured to the non-conducting material, and the outer ones, which take all the wear, are fastened to the inner in such a manner that they can be easily removed when required.

Fig. 7.



The commutator brushes, which are composed of strips of hard brass, joined together at their outer ends, are inexpensive and easily renewed. The high speed at which these machines are run, together with the form of the armature, cause the rotation of the latter to be considerably resisted by the air, and producing a humming sound, but otherwise they run smoothly; the heating of the armature being inconsiderable, not exceeding 120° Fahr. after four and three-quarter

hours' run. They are simple in construction, all the working parts being easily accessible, and the cost of maintenance low.

Fig. 4 represents the smaller Brush machine, which is identical in mechanical design with the larger, except that in the former there are two commutators, each of which is connected with alternate armature coils.

By this arrangement connections can be so made as to produce electric currents of high or low electromotive force (55 to 120 volts, as will hereafter be shown), or the conductor can be divided into two circuits, each of which can be utilized for producing its own light, or for performing other work.

In the Wallace-Farmer machine, Fig. 7, the magnetic field is also produced by two horseshoe electro-magnets, but with poles of opposite character facing each other. Between the arms of the magnets, and passing through the uprights supporting them, is the shaft, carrying at its centre the rotating armature.

Fig. 8.

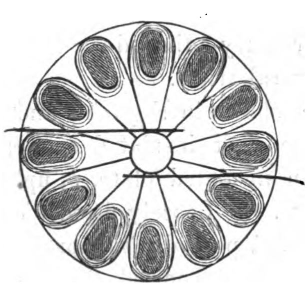
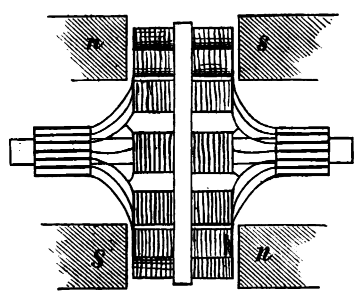


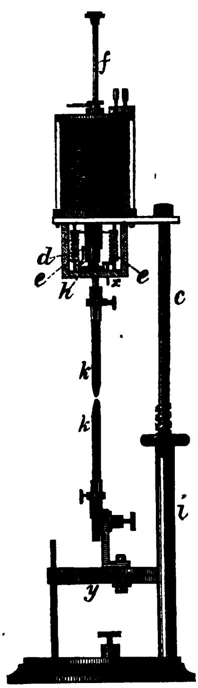
Fig. 9.



This consists of a disc of cast iron, near the periphery of which, and at right angles to either face, are iron cores, wound with insulated wire, thus constituting a double series of coils. These armature coils Figs. 8 and 9, being connected end to end, the loops so formed are connected in the same manner, and to a commutator of the same construction, as that of the Gramme. As the armature rotates, the cores pass between the opposed north and south poles of the field magnets, and the current generated depends on the change of polarity of the cores. It will be seen that this constitutes a double machine, each series of coils, with its commutator, being capable of use quite independently of the other; but in practice the electrical

connections are so made, that the currents generated in the two series of armature coils pass through the field-magnet coils, and are joined in one external circuit. This form of armature also presents considerable uncovered surface of iron to the cooling effect of the air, but its external form, in its fan-like action on the air, like that of the Brush, presents considerable resistance to rotation. In the Wallace-Farmer machine there was considerable heating of the armature, the temperature being sufficiently high to melt sealing-wax.

FIG. 10.



The Brush and Wallace-Farmer machines were accompanied by lamps, or carbon holders, which were thought by their makers to present advantages, if not for all machines, at least to be especially adapted to the requirements of their own; the usual "Serrin" lamp, which is made by M. Breguet for the Gramme machine, did not accompany the latter. The result of experiment, however, quickly established the suitability of the Brush lamp as the source of light from all the machines, and the same lamp, with carbons properly adjusted as to size, was used for the several trials.

This lamp is shown in Figs. 10 and 11, in which *a* is a helix of insulated copper wire, resting upon an insulated plate, *b*, upheld by the metallic post, *c*. Loosely fitted within the helix is the core, *d*, partially supported by the adjustable springs, *e*. The rod, *f*, passes freely through the centre of the core, *d*, and has at its lower end a clamp for holding the carbon pencil. A washer, *h*, of brass, surrounds the rod, *f*, just below the core, *d*, and has one edge resting on the lifting finger attached to the latter, while the other edge is overhung by the head of an adjustable screw stop, *x*.

The metal post, *c*, is supported and guided by a tubular post, *i*, secured to a suitable base plate. Attached to the lower end of the post, *c*, and passing out through a slot in *i*, is the arm, *y*, supporting an insulated holder for the lower carbon.

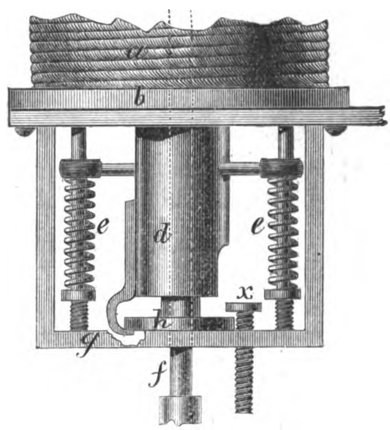
If now one conducting wire, from the machine, be connected to the base plate, and the other to the lower carbon holder, the current

of electricity will pass up through the posts, *i* and *c*, through the helix, *a*, rod, *f*, and the carbons, *k k*, thus completing the circuit.

The axial magnetism produced in the helix will draw up the core, *d*, and it, by means of the lifting finger, will raise one edge of the washer, *h*, which, by its angular impingement against the rod, *f*, clamps and lifts it to a distance controlled by the adjustable stop, *x*, but separating the carbon points far enough to produce the light.

As the carbons burn away, the increased length of the electric arc increases its resistance and weakens the magnetism of the helix, and, therefore, the coil, rod and carbon move downward by the force of gravity, until, by the shortening of the arc, the magnetism of the helix is strengthened and the downward movement arrested. When, however, the downward movement is sufficient to bring the clutch-washer, *h*, to the support, *l*, it will be released from the clamping effect of the lifting finger, and the rod, *f*, will slip through until arrested by the upward movement of the core, due to the increased magnetism of the helix.

Fig. 11.

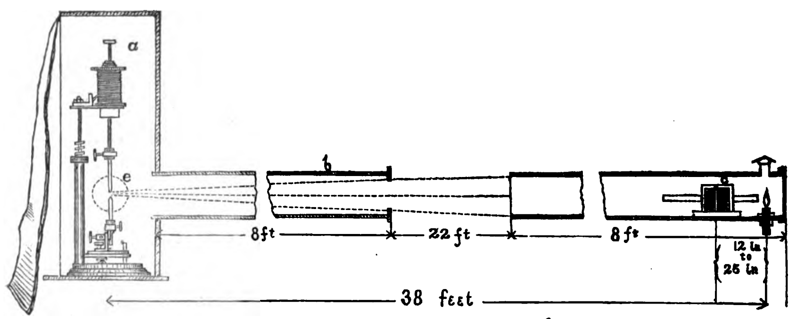


The normal position of the clamp-washer is with the edge under the adjustable stop, just touching the support, *l*, the office of the core being to regulate the slipping of the rod through it. If, however, the rod, from any cause, falls too far, it will instantly and automatically be raised again, as at first, and the carbon points thus continued at the proper distance from each other.

In the lamp used in these experiments, the helix was composed of two separate insulated wires wound together, so that, by means of suitable pin contacts, shown at the top of Fig. 10, they could be connected either in couples or end to end, thus varying the intensity of the magnetism of the helix. This, in connection with varying the weight to be lifted by the magnetism of the helix, either by loading the core or increasing the upward thrust of the springs, enabled us to adjust the lamp to suit the varying qualities of the currents dealt with.

In order to make the measurements as accurate as possible, it was found necessary so to arrange the apparatus that no reflected or diffused light should fall on the photometer, and thus introduce an element of error. The arrangement of the apparatus to accomplish this is shown in Fig. 12. The electric lamp was enclosed in a box, open at the back for convenience of access, but closed with a non-reflecting and opaque screen during the experiments. Projecting from a hole in the front of the box was a wooden tube, *b*, 6″ square inside and 8′ long, with its inner surface blackened to prevent reflection, thus allowing only a small beam of direct light to leave the box. This beam of light passed into a similar wooden tube, *c*, placed at a proper distance from the first, and holding in its farther end the standard candle, *d*.

FIG. 12.



This tube also held the dark box of a Bunsen photometer, mounted on a slide, so as to be easily adjusted at the proper distance between the two sources of light. A slit in the side of the tube enabled the observer to see the diaphragm. The outer end of the second tube was also covered with a non-reflecting hood, and the room was, of course, darkened when photometric measurements were taken. The rigid exclusion of all reflected or diffused light is believed to be the only trustworthy method of obtaining true results, and will, no doubt, account in a large measure for the lower candle-power obtained by these experiments than that obtained by many previous experimenters.

The difficulties encountered in the measurement of the light arising from the difference in color, were at first thought to be considerable, but further practice and experience enabled the observer to overcome them to such an extent that the error arising from this cause is inconsiderable, being greatly less than that due to the fluctuations of the electric arc.

The advantage to be derived from using a larger source of light than the standard candle, in measuring the electric light, was considered. A gas-flame, giving 20 candles' light, and the oxy-hydrogen light, so adjusted as to give 70 to 136 candles, were carefully measured and used as a comparison. Both of these were found unsatisfactory, and the measurements relied on for our calculations were made entirely with a standard candle, carefully corrected for any variation of consumption from 120 grains per hour.

Were much higher intensities of light to be measured, it would be well to use, as a means of comparison, a large gas-burner or a multiple-wick lamp, such as are employed in lighthouse service, its power being constantly checked by measurements with the standard candle and separate photometer; but, with the volume of light dealt with in these experiments, the candle was sufficiently large, and its direct use greatly reduced the chance of error.

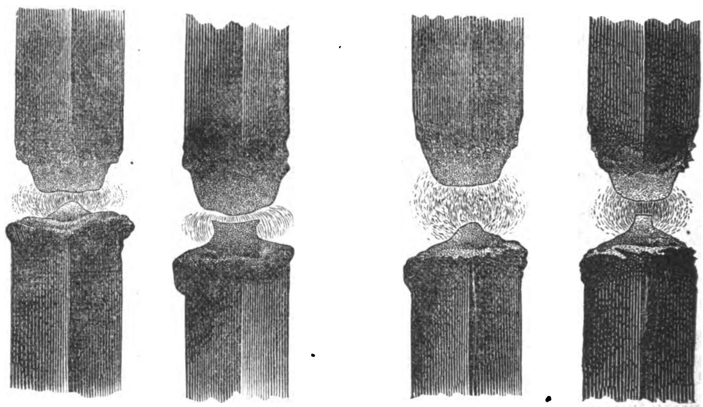
In the earlier experiments, measurements of light, current and power were made simultaneously, thus establishing standard references by which after-experiments upon the different points were connected.

In determining the amount of light produced by each machine, it was run continuously for from four to five hours, and observations made at intervals, care being taken to maintain the speed and other conditions normal. One of the most important conditions necessary to insure correct results, was the relative position of the carbon points. Great care was taken that the axes of the two sticks or pencils of carbon were in the same line, so that the light produced should be projected equally in all directions. Were the axes of the carbon pencils not in the same line, a much greater quantity of light would be projected in one direction, and the result of calculation of the light produced, based on the inverse square of the distance from the photometer, would be too great or too small, accordingly as this adjustment was in the one on the other direction.

To facilitate observations during the experiments, there was attached, at *e*, to the side of the box *a* holding the electric lamp, a focussing lens, with its axis at right angles to the beam of light, to the photometer, and an image projected upon a screen enabling the observer to see the condition and position of the carbon points without fatiguing the eye. Photographs were also taken, from time to time, at the moment of making the photometric observations—thus securing a permanent record of the condition of the carbon points.

Another difficulty in determining the exact photometric value of the electric light, is the fluctuation, or rather the moving from side to side, of the electric arc, and great care was taken so to adjust the

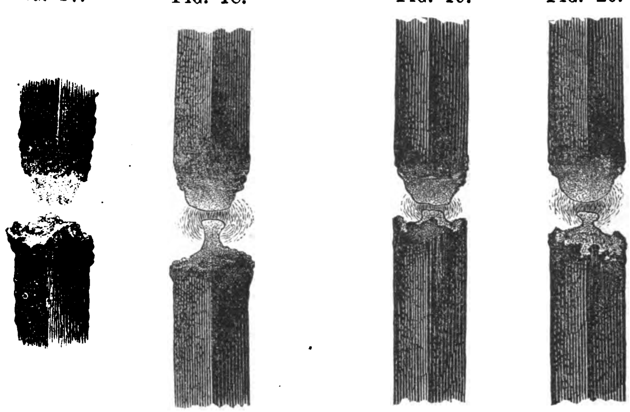
FIG. 13. FIG. 14. FIG. 15. FIG. 16.



From Large Brush Machine. From Small Brush Machine.

conditions, that the arc or flame should be steady, and equally distributed about the ends of the carbon pencils.

FIG. 17.[1] FIG. 18. FIG. 19. FIG. 20.



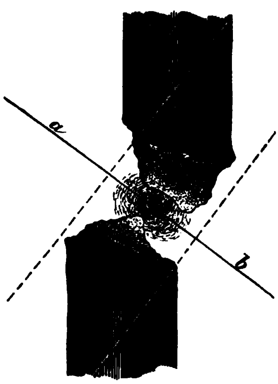
From Gramme Machine. From Small Wallace Machine.

Figs. 13 to 20 are full size, exact reproductions of the photographs taken, and fairly represent the average condition of the carbon when observations were made.

[1] The voltaic arc should have been shown in Fig. 17, as in Fig. 19. All the carbons used were coated with copper.

It was found that although there was a slow consumption of the negative carbon, there was, at the same time, a constant "stalagmitic" growth of particles carried from the positive carbon by the action of the electric current. These stalagmites assumed different forms, as shown in the cuts, but no particular form seemed to be produced by the current from the different machines, except that the deposits on the negative carbon would become greater with increased current. These deposits would build up gradually until they had assumed the forms shown in Figs. 18 and 20; then growing narrower near the base, until, by a weakening of the current by this and the consumption of the upper carbon, the lamp would readjust itself, and the piece would drop off. The effect of these growths on the intensity of the light was scarcely appreciable, except for a few seconds before and after the readjustment of the lamp.

Fig. 21.



Experiments were also made to determine what effect on the amount of light produced by so adjusting the carbons, that the front edge of the upper one was in line with the centre of the lower one. Fig. 21 shows such an adjustment, and is from a photograph taken while measuring the light produced from the small Brush machine, running at 1250 revolutions per minute, and resulting as follows:

Front, ...	2218 candles.
Side, ...	578 "
"	578 "
Back, ...	111 "
	$3485 \div 4 = 871.$

The light produced by the same machine, under the same conditions, except the carbons being adjusted in one vertical line, was 525 candles. This would seem to indicate that nearly 66 per cent. more light was produced by this adjustment of the carbons; but a close study of the conditions satisfies us that such is not the case, and that there is no advantage to be derived from such adjustment, except when the light is intended to be used in one direction only.

TABLE I.

SHOWING WEIGHT, POWER ABSORBED, LIGHT PRODUCED, ETC., BY DYNAMO-ELECTRIC MACHINES TESTED BY A COMMITTEE OF THE FRANKLIN INSTITUTE, 1877–8.

Name of Machine.	Weight in pounds.	Copper Wire in Armature: Size.	Copper Wire in Armature: Weight.	Copper Wire in Field Magnets: Size.	Copper Wire in Field Magnets: Weight.	Revolutions of Armature per minute.	Foot-pounds of power consumed.	Horse-power.	Light produced in Standard Candles: Total.	Light produced in Standard Candles: Per h.-p.	Foot-pounds of power consumed per candle light.	Size of carbons.	Length of Carbon consumed per hour: +	Length of Carbon consumed per hour: —
Large Brush, .	475	·081 in.	32 lbs.	·134 in.	100 lbs.	1340	107·606	3·26	1230	377	87·4	$\frac{3}{8} \times \frac{3}{8}$	1·78	·34
Small Brush, .	390	·063 in.	24 lbs.	·096 in.	80 lbs.	1400	124·248	3·76	900	239	137·	$\frac{3}{8} \times \frac{3}{8}$	1·91	·58
Large Wallace,	600	·042 in.	50 lbs.	·114 in.	125 lbs.	800			823					
Small Wallace,	350	·043 in.	$18\frac{3}{4}$ lbs.	·098 in.	41 lbs.	1000	128·544	3·89	440	113	292·	$\frac{1}{4} \times \frac{1}{4}$	2·45	·073
Gramme, . .	366	·059 in.	104 lbs.	·108 in.	104 lbs.	800	60·992	1·84	705	383	85·	$\frac{1}{4} \times \frac{1}{4}$	3·15	·55

We would here call the attention of those who may compare our results with those obtained at the recent experiments at South Foreland, England, to the following statement upon this point, in the report of Mr. Jas. N. Douglas, Engineer to the Trinity House, page 16 of the official report:

"I have found this arrangement of the carbons (the axis of the bottom carbon nearly in the same vertical plane as the front of the top carbon), and assuming the intensity of the light with the carbons having their axis in the same vertical line to be represented by 100, the intensity of the light in four directions in azimuth, say E., W., N. and S., will be nearly as follows:

East or front intensity, . .	287 to 100
North or side " . .	116 to 100
South or " " . .	116 to 100
West or back " . .	38 to 100
	557 ÷ 4 = 139 to 100."

* * * * * * * * *

'In measuring the candle-power of the light produced by each machine, I have given the mean intensity obtained in the direction of the photometer, the carbons in lamp working with the Holmes & Alliance machines being always arranged with the axes in the same vertical line, and the carbons in the lamp working the Gramme and Siemens machine being always arranged with the front edge of the top carbon nearly on the centre of the bottom carbon."

It is, therefore, evident that the results given by Mr. Douglas must be divided by 2·87 in making a comparison with those obtained by us.

Thus, in the table on page 31, official report, in the column headed Light produced by H. P. in standard candles, he gives for the Gramme machine condensed beam 1257, but if this be divided by 2·87 we have 438 candles, which is, no doubt, still too high, our result of 383 candles per H. P. for the Gramme, being obtained under the careful and rigid conditions before named.

[To be continued.]

Manufacture of Gunpowder without Water.—A commission was appointed in Russia in 1871, to study the question of the improvement of the powder used in rifled cannon. One of its members, Colonel Winer, taking up an idea once suggested by Saint

Robert, proposed to manufacture powder without employing water, and by compressing the materials at a temperature a little higher than that of the fusion of sulphur.

The advantages of powder thus prepared are as follows: (1) Its hygrometric property is diminished, and so it is less affected by remaining long in damp places. (2) The manufacture is less expensive, because drying rooms are dispensed with, and the mixture of the constituents takes place in mixing drums instead of mills. (3) The danger in manufacture is diminished. The powder being prepared directly in the dry state, only small quantities are treated at one time.

Winer was charged to make experiments in this direction in the works at Okhta, and he made the necessary arrangements for the purpose. The latter consisted of a hydraulic press, to which were adapted two hollow plates of copper, connected by two pipes of the same metal for the passage of steam. The lower plate was screwed on the plate of the press, which was fixed on the piston, and communicated, through a caoutchouc tube, with the steam pipe. The upper plate was fixed, and put in communication with the steam pipe by means of an iron pipe. The pulverulent and dry mixture, prepared in the drum, was spread uniformly on the lower copper plate, then the piston was set in motion, and pressure was produced for ten minutes. The disk of powder thus obtained was a perfectly homogeneous mass. The temperature of the steam was about 120° C. With a pressure of 130 atmospheres, measured in the manometer, cakes were got with a density of 1·80 to 1·9; with 30 atmospheres, it was 1·66 to 1·7. These pressures correspond respectively to 114 k. and 25·4 k. per square centimetre. The cake was reduced to grains by means of crushing cylinders. By means of a sieve the grains were isolated from the rest of the powder; and lastly were discharged into bags.

Only in 1874, after having experimented with a long series of compressed powders of different grain and density, did Winer find one which answered the requirements. This powder had a density of 1·6, a grain of 6 to 8 mm., and gave with a charge of 2·250 k. in a range 4-piece, an initial velocity of 471·5 mm. in the projectile. The tension of the gas was 1366 atmospheres.—*The Iron Age.*

FUTURE WATER-SUPPLY OF PHILADELPHIA.

By Henry P. M. Birkinbine.

In the last fifty years great improvements have been made in the sanitary condition of cities, and with the most satisfactory results; so that not only the comfort and convenience, but the health and longevity of these crowded centres of population have been greatly promoted.

The marked success which has attended the introduction of a copious supply of water and drainage by systems of sewers, has increased the interest in such matters, and led to great earnestness and activity in the investigation and application of these important means of sanitary improvement; so that at the present time every town of any pretensions has availed itself of either a water-supply or system of underground drainage, or both combined, or is seeking information on these subjects. Philadelphia, in these, is not behind any other city in the country. It is true there are defects in our present arrangements to be corrected, and much yet to be done to make them complete; but in their present condition they will compare favorably with most of the larger cities. The water-supply has been ample, completely distributed, and, until lately, of a satisfactory character.

A city of the magnitude, wealth and population, present and prospective, of Philadelphia, must not be satisfied with merely meeting present wants, and making arrangements to supply them as the emergency arises; but a proper and judicious foresight must be employed in designing and carrying out its systems of water-supply and drainage.

The question proposed for discussion in this paper is the future water-supply of Philadelphia. This has occupied considerable attention, and a number of schemes have been presented to the consideration of Councils and the public. Among these are:

1. Increasing the water-power at Fairmount.

a. By store dams to keep up the flood water, and utilize it for power in times of drought.

[1] Paper read before the Franklin Institute, February 20th, 1878.

b. By purchase of the power created by "Flat Rock" dam.

c. By raising Fairmount and Flat Rock dams.

2. Pumping the water from the Delaware and Schuylkill by steam machinery, by increasing the number and power of the pumping engines.

3. Bringing the water from the Delaware at Lambertville to near the city by gravitation, and pumping it into the reservoirs by steam.

4. By gravitation, either from the Delaware River, or the Perkiomen Creek, a tributary of the Schuylkill.

Quality of Water.

Next in importance to the character of the air we breathe is that of the water we drink; therefore, in considering a water-supply, there is no question of such marked importance as the comparative purity of the source from which the supply is drawn. No matter how much the cost of securing better water may exceed that required to furnish an inferior quality, the expense should not be permitted to interfere, so long as it is in the power of the city to meet it. So with any other sanitary improvements, money considerations should never weigh against health and longevity.

The question of what constitutes good potable water, is one which has generally been left to the chemists to examine and decide; but they differ in their method of analysis and conclusions arrived at, and confess that they are unable to decide by analysis alone. Messrs. Booth and Garret, in their able report on the chemical examination of the waters of the Delaware and Schuylkill, made to the Commission of Engineers, say: "We may as well confess that chemists are uncertain as to the nature of the organic matter which causes the unhealthiness of a water.[1] Chemically pure water is not attainable from natural sources. Rain water takes up impurities in its passage through the atmosphere; springs, wells, brooks, rivers, and lakes, all contain mineral salts and organic impurities, dissolved by the water in passing through the earth, or over their drainage areas. Most of these may be discerned and their character and amount determined by analysis; but to obtain the best results, a noted chemist has stated,

[1] Report on the water-supply of the city of Philadelphia, made by the Commission of Engineers, 1875, page 108.

in substance, that nothing exceeds a critical examination of the drainage of a given source; for by a knowledge of the geology, topography, physical and commercial features of the water-shed, the quality of the water obtainable from it is best determined."

The character of the future supply for this city is thoroughly and ably discussed by Julius W. Adams, C. E., one of the commission upon the water-supply of Philadelphia,[1] and to this report I would refer those who desire to examine the subject more at length.

A special committee of the Commissioners of Fairmount Park reported upon "*The Preservation of the Purity of the Water-Supply,*" and presented the report to the public in a pamphlet, in 1867. It is to be regretted that many of the statements and figures of this report cannot be relied upon; and yet it contains matter of importance in the discussion of this subject. On the first page there is the following statement:

"The superior quality of the water of the Schuylkill at Philadelphia, chemically considered, *when free from impurities introduced by human agency*, cannot be doubted; all analyses yet made place it in the first rank as a water proper and desirable for the ordinary domestic uses."

To sustain this assertion of the chemical purity of the water, a table is inserted on page 4, by which it is proposed to show that the water supplied to Philadelphia from the Schuylkill is better than the average of the cities noted in this table; but there are errors in this table, which, when corrected, do not sustain the assertion. So far as chemical analysis exhibits anything of the nature of the water of the Schuylkill, it shows a steady increase in the amount of solid matter to the gallon, evidently introduced by human agency. Thus in the analysis of the water made in

1842	there	were	4·42	grains	to the	gallon	(Boye).
1850	"	"	5·50	"	"	"	(Silliman).
1854	"	"	6·10	"	"	"	(Booth and Garrett).
1862	"	"	7·04	"	"	"	(" ").
1875	"	"	8·183	"	"	"	(Cresson).

But the relative amount of solid matter alone per gallon does not form a reliable indication of the value of the water for drinking and household purposes.

[1] See Report, 1875, pages 57 to 100.

The character of the material from which the solid matter is derived, and the condition it may be in when the water is presented for use, are the only proper standard for judging of its value. But there is frequently great difficulty in detecting the presence of deleterious matter in water. It may be perfectly limpid, and, to the eye, satisfactory, and yet contain objectionable matter. So with all the other means of examination.

The method above suggested, of an examination of the drainage area, is practically the best means of judging of the fitness of the water for a public supply for a city.

SCHUYLKILL.

The water of the Schuylkill, when free from objectionable matter introduced by the agency of man, cannot be surpassed in desirableness for all purposes presented by the wants of a large city. As a supply for Philadelphia it is inexhaustible, even at its lowest stages. Its smallest flow during the seasons of extreme drought may be set down as about 200,000,000 gallons per day: four times the present requirements of the city.

The drainage area of the Schuylkill above Fairmount dam is as follows:

Schuylkill County,	324	square	miles.
Berks "	841	"	"
Lebanon "	43	"	"
Lehigh "	73	"	"
Montgomery "	396	"	"
Bucks "	82	"	"
Chester "	161	"	"
Philadelphia "	22	"	"
Total,	1942	"	"

The water from Schuylkill County is entirely from the sandstone formation of the coal measures, and is almost free from mineral salts of any kind, except that pumped or flowing from the coal mines. The character of this mine drainage and its peculiarities has been so often described, and the means of correction by the lime water in Berks County, that it need not be repeated here.

One of the conclusions arrived at, in the special report of the Park Commissioners, is: "That the amount of acid caused by the coal

mines has probably reached its maximum." That this is not the case will be demonstrated by the following considerations:

The mine refuse, of which there are immense quantities about the mines, contains pyrites, which furnishes the acid water. These heaps of mine waste are constantly being disintegrated by the action of the elements, and washed into the stream. The bitter water from the old abandoned mines continues to flow. When the upper veins are worked out, shafts have been and are being sunk to work the underlying veins. The workable veins have not all been developed, and new mines are and will be opened; so that the maximum has not been reached.

The mine water in times of drought seems to be making its way down the river, and its presence may be observed from the cars, in the Big (Lewis's) dam below Reading, by the light blue color of the water, and the deposit upon the wood-work of the dam.

The limestone water which forms so large a part of the streams coming in in the vicinity of Reading, produces no deleterious results; in fact, it is beneficial in correcting the acidity of the mine water.

The washings from the other mines, which are principally iron, from railroad cuttings and embankments, and from plowed fields, so far as they are merely mineral, are only objectionable from the fact that they render the water turbid at times.

The objectionable feature of the water is derived from organic matter; from cultivated fields, factories, stables, and house drainage. It is difficult to estimate either the quantity of this which finds its way into the river, or the proportion that ultimately reaches the water-works, or the condition the objectionable matter may be in when it arrives at the works; all these are important considerations, but most difficult of solution.

By the census of 1870, there was a population of 340,790 living on the drainage area of the Schuylkill above Fairmount dam. Allowing an increase of about 15 per cent., it would make the present population 400,000. One-half of these reside in the cities and larger towns, and would give an average of about 200 to the square mile. The population living on the area drained by the Thames, England, from which the city of London procures its principal supply of water, is 270 to the square mile. Notwithstanding the means resorted to by many of the towns in the drainage area of the Thames for utilizing their sewage, or purifying it, and the large expenditures the

companies taking water from the river have incurred of late years, for subsiding reservoirs, filter beds, and store reservoirs, to purify the water, the Board of Public Works of London are again considering the subject of securing a supply of better water from some other source, if only for drinking and culinary purposes.

With the return of business activity, there are few sections of our country which will become as densely inhabited as the drainage area of the Schuylkill; for none possess greater inducements for the locating of industrial establishments.

The Board of Health of the city of Reading, in their report, 1876, page 10, estimate the quantity of animal waste accumulating in the limits of the city in 24 hours, to be 2·51 tons of excrement, 25·14 tons of urine, 154·28 tons of liquid garbage. The population of the city at that time was 40,100.

Reading may be said to be without sewers; therefore, but a small proportion of this objectionable matter reaches the river directly; but the time has come when a complete system of sewerage for that city is a necessity, and surveys are now being made for the purpose of adopting a system of underground drainage.

Of the number of deaths in that city, 1118, during 1876, 412 are reported to have died from zymotic or preventable diseases.

These remarks in reference to Reading will hold good in the other large towns in the drainage area. So that while there may be little to fear at present from town drainage, what the future will be, can only be conjectured. What effect the river may have upon objectionable organic matter drained into it to render it innocuous, is a question of great importance, but undecided. It is claimed by some that the oxygen in the water acts upon the organic matter and destroys it (burns it up), leaving only the ashes, which subside and fall to the bottom, and that this is done in a short time, or during the ordinary flow of the stream of from eight to twelve miles. Others, of equally reliable authority, claim that when water is once contaminated by sewage, it is not fit for use, and that the flow of over one hundred miles will not restore it to its former potability.

This question occupied much of the attention of the Royal (British) Commission on the Pollution of Rivers, and the opinions of a number of experts are arrayed on both sides of the question. The evidence on the affirmative side—that is, that the water has in itself the power of self-purification after contamination, in a comparatively short

time—is collected, and can be found in a paper on the "Sanitary Chemistry of Water," Vol. I; Public Health papers of the American Health Association, by C. F. Chandler, Ph. D., M. D., LL. D. The position that there is danger in using the water after once being contaminated, is sustained by the collection of a large amount of evidence from the same reports of the commissioners on the pollution of rivers, and applied to the Schuylkill, by Julius Adams, C. E., in the report on the water-supply of the city of Philadelphia, made by the commission of engineers. The evidence on both sides is supported by chemical tests, experiments and observations, principally upon the River Thames, from which London draws most of its water-supply. Dr. Charles M. Cresson, in his analysis of the Schuylkill water, gives as one of the results: Sewage, 0·2142 grain to the gallon. Booth and Garrett object to the use of the term, and deny the presence of sewage in the Schuylkill water.

The most objectionable drainage into the river is that of Manayunk, because of quantity and close proximity to the intake of the different works. This consists of house and factory drainage, and amounts, in extreme dry seasons, to more than one-twentieth of the entire flow of the river. Of this drainage, that from houses, although it forms the smaller part, is the most obnoxious.

The subject of getting rid of this objectionable matter has occupied much attention, and several schemes have been suggested, the latest by the Chief Engineer of the Water Department, in a proposition, in his last report, to intercept all the drainage above the canal, and convey it by a sewer to the Delaware. No estimate of the cost of this work is given. It will be between six and seven miles long, and principally tunneling; but it will only intercept the drainage above the canal, leaving almost the entire factory drainage and some of the town still flowing into the Schuylkill. The character of the factory drainage will be exhibited by an analysis made by Dr. Charles M. Cresson, of one of the largest and most objectionable contributors. The quantities are in pounds per one million gallons of discharge: Ammonia, free, 48·57 lbs.; albumenoid, 206·42 lbs.; from nitrates, 29·14 lbs.; sewage, 2064·28 lbs.; sulphuric acid, trace; chlorine, 388·57 lbs., or more than one ton per million gallons—2737 lbs.

The character of the water in the Schuylkill has changed greatly in the past fifteen years, and even to the unaided senses of sight,

smell and taste, has perceptibly grown more impure. Chemical analysis sustains this, as shown above.

The River Schuylkill takes its rise in the Broad Mountains on the north, and the water-shed has its divide between it and the Lehigh, near Topton, on the East Pennsylvania R. R., and between it and the Susquehanna, near Lebanon, on the Lebanon Valley R. R.

The navigation company has constructed store reservoirs upon the upper waters: Silver Creek, 1500 feet above tide, containing 42,780,500 cubic feet; Tumbling Run, lower dam, 647 feet above tide, storage capacity 25,546,512 cubic feet; upper dam, 694 feet above tide, storage capacity 39,858,612 cubic feet.

The Pottsville Water Company have also two store reservoirs; the higher and larger, on Eisenhuth's Run, at an elevation of about 1700 feet above tide, will store about 52,000,000 cubic feet. The navigation of the river has been improved by a system of canals and dams reaching, at present, from Fairmount dam to Schuylkill Haven. In former times the canal extended up to Port Carbon; but the upper portion, above Schuylkill Haven, has been abandoned, on account of the washing of the waste material from the mines into the canal and pools, the number of locks and scarcity of water. The Union Canal follows the Tulphehocken its entire length. There are several store reservoirs for feeding the upper levels. The principal supply of the summit level is pumped from the Quittapahilla and Swatara, on the other side of the divide between the water-shed of the Schuylkill and Susquehanna.

The mill-sites in the streams flowing into the Schuylkill are generally improved, and furnish power for saw-mills, grist-mills, and factories of various kinds.

The effect of the numerous dams upon the water is important in the consideration of the purity of the stream or its correcting power. The pools receive and retain much of the solid matter washed into them; they also allow much of that which is held in suspension to deposit, and the water to flow off bright and clear. Matter held in solution may be in part dissipated by chemical action, produced by the oxygen in the water, light and air; but how far this is the case, we have no positive means of ascertaining.

The alluvium collected in these dams and pools contains a large percentage of organic matter in various stages of decomposition.

Some idea of its character and amount may be formed from the deposits in Fairmount pool, from Columbia Bridge to the dam. This amounted, by actual hydrographical surveys between 1861 and 1864, to 3,313,681 cubic feet; and between 1864 and 1866, to 6,642,584 cubic feet, or an average of 5430 cubic feet per day for the five years.

The effect of flowing through the canal, and the traffic of the boats, cannot be of any advantage to the purity of the water.

There are three conditions in which to consider the river:

1. That of its minimum flow in times of drought.
2. That of its mean flow when free from storm water.
3. That of its maximum flow in times of freshets.

The Minimum Flow of the River at Fairmount is estimated by Mr. James F. Smith, chief engineer of the navigation company, to be 245,000,000 gallons; measurements made in September, 1874. By my own calculations, I have several times estimated the minimum flow of the river, and found it about 200,000,000 gallons. My estimates were made from the water used as power, and that pumped at Fairmount, and the amount used for passing boats through the locks, and the estimated leakage. This calculation is sustained by using the ascertained minimum flow of the Croton, 0·3 cubic foot per second, from 1000 acres. This would make the amount, for the Schuylkill, 241,000,000 gallons per day. From this must be deducted the evaporation for the summer months, 0·115 inch, from the surface of the river, dams and pools, making a reduction of 40,000,000 gallons, leaving about the minimum as per my calculations. In the forty days ending September 16th, 1876, the calculated average flow of the Schuylkill was 230,788,880 gallons per day. During this time there were, no doubt, days when the flow fell below 200,000,000 gallons per day. These calculations were made by the Water Department, upon the same basis I used.

Mean Flow of the River.—The measurements and estimates of the mean flow of the stream generally agree. The first of these were made by Rittenhouse, early in the present century, for the purpose of ascertaining the value of the river for navigation purposes, and corresponds with the measurements of others and my own, and makes the mean flow of the stream, when free from storm water, 650,000,000 gallons per day.

Maximum Flow.—By a comparison of all the available tables of rain-fall, kept in the drainage area, the yearly average may be taken as 45 inches. A part of this is evaporated, a part absorbed by vegetation, another portion may go to feed perennial springs beyond the drainage area of the river; so that the amount which reaches Fairmount is about 18 inches of the entire precipitation. This would give a mean daily flow equal to 1,665,000,000 gallons. Over 1,000,000,000 gallons of this amount pass over the dam in times of freshets; sometimes in quantities beyond our ability to calculate. The mean daily flow would all be passed over Fairmount dam with a depth of 10 inches on the comb of the dam. Sixteen inches would vent the average for two days in one. Beyond this we have no reliable formula by which to calculate the amount discharged over the dam. Oct. 4th, 1869, there was a depth of 11·46 feet above the comb of the dam.

While the mean flow of the river has maintained itself the same for over sixty years, the maximum and minimum have been farther removed from each; that is, in low stages of the river the amount has decreased, and the freshets have been more frequent, and the volume of water brought down much greater.

The records of the rain-fall kept in the vicinity of this city, for over fifty years, show marked increase in the precipitation every decade.

As a proportion of the water falling upon the drainage area finds its way into the river, there should be, and no doubt is, an increased flow in the stream; but as this increase passes off in floods, it is of no practical value for power. Many of the water-powers in the drainage, once improved and utilized, are now abandoned and allowed to go to ruin. This change in the character of the river may be accounted for by the cutting off of the forests, which formerly held back the rain water, by roots, mosses and undergrowth, and allowed a larger proportion of it to find its way into the soil, to replenish the perennial springs. This water now flows directly off, and, as a consequence, instead of a steady flow into the river and its tributaries, they are yearly assuming more the character of a torrent, subject to frequent droughts and to frequent floods.

At times of freshets and floods, some of the matter deposited in the pools or dams is stirred up and carried down the stream, and

our water is frequently discolored and filled with matter held in suspension. Not all of this is innocuous mineral matter, but much of it is made up of organic matter in various stages of decomposition. The danger of an admixture of such organic matter, even when with a large volume of pure water, was shown at Chicago, at the time of a freshet in the river, in April, 1876. The water supplied to the city was so much affected, as to be perceptibly impure to all the senses, and the result was a marked increase of bowel complaints, some resulting fatally. The water continued impure for a week. When the large volume of pure lake water, to be contaminated, is taken into consideration, and the distance from the mouth of the river to the crib, or intake of the water-supply, the danger of using water with the smallest conceivable admixture of such matter is made manifest.[1]

There is no doubt but that the river grass, found in such abundance in many parts of the stream, during the summer, does much to purify the water. It is claimed that since its introduction into the rivers of England, it has had a most beneficial effect. It is a new thing there, and has been transplanted, by some means not now known, during the present century, and has found its way into many of the rivers.

From the above statements the following conclusions may be arrived at:

1. That, notwithstanding the large population upon the area drained by the Schuylkill, there is at present but a small percentage of sewage drained directly into it from the large towns.

2. That sewerage has become a necessity for all of the large towns, and will be speedily constructed; when a large amount of sewage will be discharged directly into the river.

A proposition is before the city of Philadelphia to divert a portion of the most objectionable town drainage from the river, viz.: that of Manayunk, above the canal. This will do much to restore the river to its former condition of purity, but will only be a partial relief.

3. The most objectionable matter in the river is the organic matter which settles in the pools during its ordinary stages, but which is stirred up and carried down the stream in various conditions of decomposition during freshets.

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[1] Report, 1876, p. 65.

4. By cutting off the forests and clearing the ground, the minimum and maximum are further removed from each other. The river is more frequently low, and less water flowing in it, and is more frequently affected by storms, and, as a consequence, turbid.

5. That when the towns on the drainage of the Schuylkill construct sewers, the amount of sewage drained into the river will become a large portion of the stream; one-half of the town dwellers would discharge an amount equal to one-twentieth of the volume of the river in extreme low stages.

Delaware River as a Source.

The quality of the water furnished by the Delaware is unexceptionable. There are comparatively few towns of importance in the drainage area, and nothing of a character to deteriorate the water. If the water is taken between Trenton and Bull's Island, there are seasons of the year when it becomes objectionable, on account of the large amount of water abstracted from the river at Bull's Island, to feed the Delaware and Raritan Canal, leaving but a small amount to flow in the channel of a large river, and, as a consequence, stagnant pools of water occupy parts of the bed of the stream. In seasons of drought there is practically no water flowing in the channel below Scudder's Falls, where the Trenton Water-Power Company take the entire flow of the river. The water for some distance below Easton would be objectionable on account of the drainage of Easton and Phillipsburg, and the water of the Lehigh, which is subject to all the objections presented against the Schuylkill. If the water for the supply of Philadelphia is obtained from the Delaware, it should be taken either above Easton, at Bull's Island, or at some point in the tidal portion of the stream, as near the city as it is possible to come, and evade the influence of the city sewage. The greater volume of water in the river between Trenton and Philadelphia, and its constant motion by the ebb and flow, will do much to maintain its purity. Therefore, with the exception of that portion of the stream between Trenton and Bull's Island, and a short distance below Easton, the river furnishes an abundant supply of unexceptionable water for all possible future demands of the city.

The Perkiomen as a Source.

Character of the Water.—The Perkiomen is the largest tributary of the Schuylkill. The country drained by it is well adapted for collecting water for the supply of a city, the formation being principally trap and sandstone, with from 8 to 10 square miles of lime. There are also some iron mines, now worked, near Boyertown. The old copper and lead mines are below the point where the water would be taken. There are no manufactories which would impair the character of the water, and no towns of any importance in the drainage area. The country affords no inducements for industrial establishments, nor is it likely to become thickly settled. The number of inhabitants has been slightly augmented by the construction of the railroad, but, with this exception, there has been but little, if any, increase of population in the last fifty years. Nearly one-third of the entire drainage area is still wooded, and likely to remain covered with timber. The soil is of little value for tillage. A large proportion of the cleared land is kept in grass, milk and butter being the principal products of the country.

The commission of engineers, in their report upon the water-supply of Philadelphia, in referring to this source, of which they made personal examination, say that it is free, and likely to remain free, from causes of pollution, p. 38. The Park Commissioners claim that "the Schuylkill can be better protected from pollution than streams of smaller size which have been proposed to supply the city," p. 9. This is the only statement made by any who have examined this source, which reflects upon its desirableness, so far as the quality and maintenance of the purity of the water are concerned. Storing of the water in large reservoirs would tend to purify it. All matter held in suspension would sink, and the action of light and air would do much to dissipate organic impurities.

Quantity.—The public generally have doubted the capacity of this stream to furnish an adequate supply for the future demands of the city. The natural flow of the stream would not meet the present demand in seasons of drought. The minimum flow of the stream, using the same bases for estimating as were used for the Schuylkill, is 30,000,000 gallons per day. To utilize a stream of the character of the Perkiomen, impounding reservoirs are necessary, so that the flood water may be stored to supply deficiencies in times of drought.

The Perkiomen takes its rise in the South or Lehigh Mountains, which have an elevation of from 900 to 1000 feet above tide. Where the proposed dam would be located, a trap-dike crosses the valley, and probably stops all the water flowing in underground channels; so that the entire rain-fall upon the drainage area, except that absorbed by vegetation, or lost by evaporation, passes this point. The available drainage area is 220 square miles; from this area the mean daily flow of the stream past the location of the proposed reservoir, by carefully made estimates of William J. McAlpine, C. E., shown in a table, p. 132, report of commission of engineers, is an average of 311,000,000 gallons per day. Using the data presented by the special committee of the Park Commissioners, for the mean daily flow of the Schuylkill past Fairmount dam, applied to the flow of the Perkiomen at the proposed store reservoir, the daily average flow is 250,000,000 gallons per day. My own estimate, as shown in my report to Councils, 1866, p. 21, is 240,000,000 gallons per day. In Mr. McAlpine's estimate, he utilizes from 20 to 90 per cent. of the rain-fall, dependent upon the season of the year, making an average of 59⅛ per cent. of the annual precipitation, or 28·41 inches. My estimates are based upon 23·12 inches of rain-fall made available for city supply.

The commission of engineers, by taking the lowest average rain-fall for 20 years, and making every allowance for possible loss, make the minimum flow 160,000,000 gallons per day. My own estimates, taking the lowest recorded annual precipitation in Philadelphia (1848), and estimating 50 per cent. utilized, would give a minimum daily average of 183,000,000 gallons. It may, therefore, be confidently asserted that this source alone will furnish an abundant supply of unexceptionable water for a city of over 2,000,000 inhabitants. Should a demand greater than this ever arise, the East Perkiomen, and Skippack, large tributaries entering the main stream below the proposed dam, could be intercepted and utilized.

In giving the above data, I have purposely laid stress upon the opinions of those who have critically examined the source, and used them to demonstrate the correctness of the position I assumed when acting as Chief Engineer of the Water Department in 1864. I recommended to the Councils of the City of Philadelphia the utilization of the Perkiomen by gravitation, as the best and most economical source of future water-supply.

MEMOIRS ON THE LIQUEFACTION OF OXYGEN, THE LIQUEFACTION AND SOLIDIFICATION OF HYDROGEN, AND ON THE THEORIES OF THE CHANGES IN CONDITION OF BODIES.

By R. Pictet.

[Translated for the Journal of the Franklin Institute, by P. Pistor, M. E.]

In order to facilitate the perusal of these memoirs, they have been divided into six chapters; each treating of a special subject of this investigation.

The first chapter is devoted to general remarks. Therein we develop the object of these memoirs and the physical laws relating to the change of condition of a body. The second chapter contains a description of the apparatus employed. The third chapter gives the experiments themselves. The fourth chapter is devoted to calculations for the reduction of the observations; a determination of the density of liquid oxygen, of the lowest temperatures and highest tensions of the vapors of liquid oxygen. The fifth chapter is devoted to hydrogen. The sixth chapter gives the conclusions which may be drawn from these experiments and their results.

I. General Remarks.

All the phenomena of heat were originally revealed to man through the medium of the sense of touch.

The sensation of heat and cold, born of the peculiar modality of the sense of touch, was first attributed to a special fluid, phlogiston, or heat distributed in different degrees through all bodies. This theory, admitted for many centuries, was the outgrowth of the hypotheses then advanced on light, and had to be almost forcibly displaced from the rather analytical minds which guided science at that time.

But gradually several categories of phenomena were ranged in the chapter of heat, although the sense of touch was completely excluded from the study of these manifestations of heat. Calorimetry took birth as well as the study of the change of condition of bodies. The term, latent or insensible heat, still remains in scientific literature, and

defines well that particular phase through which the human mind has passed.

The new path opened to investigation a field so rich in discoveries of all kinds, that all human knowledge may be said to have profited by it.

The mechanical theory of heat, which has resulted from it, complete, is an immense work, in which philosophy as well as physics and chemistry have found a rich harvest of facts and interpretations of indications, which have thrown a strong light on the chaos in which investigators formerly blindly groped.

This magnificent discovery consists in completely ignoring phlogiston, or heat as a body, and in explaining it by the movement of the particles constituting the body.

The study of heat has become the study of motion; the closely related motion of atoms, of invisible molecules, which cannot be distinguished by the microscope, but can be demonstrated to-day in as satisfactory a manner as if it could be seen.

The battle-ground has thus been entirely transferred, and the study of the constitution of bodies has become an essential requirement to the study of heat. These two chapters are inseparable, and should be treated together.

The theory of gases, so admirably developed by M. Clausius, is one of the most remarkable and immediate results of this scientific progress.

The object we pursue in this pamphlet is to make use of the mechanical theory of heat, which has already become classical, in explaining several anomalous or seemingly anomalous phenomena, which appear to be more or less contradictory to the general laws of physics, or to the theory of M. Clausius; and to bring them back to phenomena of the same nature, showing no contradiction to the above cited laws, by the experimental method.

In order to put the question in a precise manner, we will describe the phenomena we see in a few words.

Almost all known bodies are susceptible of passing through the three conditions: gaseous, liquid and solid. For the same body, these three conditions require different temperatures. The solid condition corresponds to the lowest temperature, the liquid to a higher, and the gaseous to a still higher temperature.

It is consequently assumed that the particles constituting the body, called molecules and atoms, attract and have a tendency to approach each other, but that an opposing force resists this tendency and counteracts this attraction. This force is the "caloric motion" which is dependent on the temperature.

This general law involves the assumption that all bodies, without exception, are constituted in an analogous manner, and that all the constituent particles are subjected to the forces of cohesion and the motion of heat.

From which may be deduced, that if the heat diminish gradually in a gaseous body, the molecular cohesion will forcibly conduct it into a liquid or solid state; or else the hypothesis of the general application of the law would be erroneous.

M. Regnault, in his memorable experiments on the compression of gases, has thrown light on an important point: all compressed vapors, on approaching their point of liquefaction, compress more than is indicated by the law of Mariotte and Gay-Lussac; a law which applies to an ideal, absolutely perfect gas.

This result evidently shows that the molecular forces, perhaps cohesion, aid the pressure in order to bring still closer together the free molecules, which are within the sphere of reciprocal attraction, ready to precipitate themselves as liquid drops.

The vapors of all known fluids—the vapor of mercury, of water, of alcohol, of sulphuric acid, of carbonic acid—pass through the same phase; they all compress more than would a perfect gas.

Only the so-called "permanent gases" do not pass through this phase peculiar to vapors, named thus to distinguish them from perfect gases. They even show a contrary result under the action of strong pressures; that is, they compress less than the law of Mariotte and Gay-Lussac would require. M. Regnault has shown that hydrogen in particular is appreciably less compressible than nitrogen and oxygen; the last two gases follow the law of Mariotte almost absolutely, with but the slightest variations for pressures of 30 and 50 atmospheres.

If the difference observed between the volume of a body at a given pressure and temperature, and the volume which it should occupy if the law of Mariotte and Gay-Lussac were strictly true, be called the "co-volume," we find that the co-volume of vapors is always

positive, whereas that of the permanent gases is almost zero or is negative.

Adopting these results as a basis, and admitting M. Clausius' theory of the constitution of gases and vapors, we are obliged to acknowledge that certain molecules, though very close, tend rather to repulse than to attract each other; as the tension increases more rapidly than the calculation would indicate, assuming the cohesion to be equal to zero.

For a difference in volume of $\frac{1}{2}$, that is, on compressing a gaseous mass, whose volume is one, and reducing it to a volume equal to $\frac{1}{2}$, the pressure has more than doubled for the permanent gases, but for vapors is less than double the initial pressure.

It is evident that these results form a powerful argument against the universality of cohesion, which accordingly would be but an accidental force, peculiar to certain bodies, and might even be replaced in some cases by a repulsing and opposite force.

M. Natterer, Professor of Physics, at Vienna, has endeavored to determine experimentally, to what point the so-called permanent gases might be compressed, and what would be the influence on the volume, of enormous pressures, which might even reach 3000 atmospheres. By means of this gigantic power he hoped to accomplish a change of condition, owing to the very considerable approach of the gaseous molecules towards each other. Had the cohesion of the gaseous particles been but ever so slight, it would seem, on first consideration, this change should have taken place. The following are some of the figures obtained by M. Natterer from his experiments, made in 1854, following the observations made by M. Regnault.

HYDROGEN, OXYGEN AND NITROGEN.

M. Natterer has subjected hydrogen, oxygen and nitrogen to pressures varying from that of the atmosphere, to one of 2790 atmospheres. He conducted his experiments in the following manner:

He introduced successively into the same enclosed space, equal volumes of hydrogen, for instance, 10 volumes equal to the initial one. A peculiar and very sensitive manometer indicated the corresponding pressure. In the following table the first column gives the volumes of gas compressed into the volume of the first one. The second column gives the recorded pressures in atmospheres; and the third gives the differences between each two succeeding pressures.

HYDROGEN.			OXYGEN.			NITROGEN.		
Volume.	Atmosphere.	Difference.	Volume.	Atmosphere.	Difference.	Volume.	Atmosphere.	Difference.
0	0	8	0	0	7	0	0	5
8	8		7	7		5	5	
18	18	10	17	17	10	15	15	10
28	28		27	27		25	25	
68	68	10	157	157	10	75	75	10
78	78		167	167		85	85	
128	134	12	227	232	11	225	240	12
138	146		237	243		235	252	
238	274	13	277	287	11	275	306	15
248	287		287	298		285	321	
358	438	16	357	382	12	355	444	22
368	454		367	494		365	466	
418	539	17	417	463	16	415	600	30
428	556		427	479		425	630	
458	608	19	457	539	24	455	729	35
468	627		467	563		465	764	
488	665	20	487	614	27	485	840	42
498	685		497	641		495	882	
538	775	24	537	764	36	535	1095	64
548	799		547	800		545	1159	
598	930	28	597	1010	46	595	1546	94
608	958		607	1056		605	1640	
668	1134	30	647	1284	70	645	2016	110
678	1164		657	1354		655	2156	
758	1434	37				675	2394	128
768	1471					685	2522	
828	1701	40				695	2654	136
838	1741					705	2790	
878	1904	44						
888	1948							
908	2044	54						
918	2098							
948	2277	70						
958	2347							
978	2505	89						
988	2594							
998	2689	101						
1008	2790							

Let us examine the three gases: Oxygen only reaches a pressure of 1354 atmospheres, the highest limit attained with that body.

The above table proves, in a very striking manner, that the law of Mariotte is absolutely false, as soon as a pressure of 100 atmospheres has been exceeded, and that is the case for all three gases examined. For relatively moderate pressures, oxygen follows the law of Mariotte the most closely, better than hydrogen. For higher pressures, on the contrary, the deviations are strongly marked, and when 657 volumes of oxygen have been compressed, the pressure, which theoretically should be 657 atmospheres, is equal to 1354 atmospheres, more than double.

Under the same conditions hydrogen shows a pressure of 1104 atmospheres, and nitrogen of 2156. It is evident from these figures that gaseous molecules must repulse each other with considerable energy, as an increase of 10 volumes of oxygen causes an increment of 70 atmospheres of pressure, and of 110 for nitrogen.

Interpreting these results by means of a curve, whose abscissæ represent the compressed volumes, and whose ordinates represent the corresponding pressures; they clearly indicate a manifest tendency towards a limit of compressibility which cannot be exceeded. This limit corresponds to that point of the curve, for which the ordinate becomes an asymptote; then the pressure increases indefinitely for a very small increment of gas, introduced into the original volume. That is, probably, what should happen, when the molecules of gas had been forced into absolute contact by the simple act of compression. The inter-molecular spaces becoming zero, all diminution of volume is impossible on account of the impenetrability of matter.

These conclusions, based on incontestable facts, seem to invalidate the universality of cohesion in a serious manner. According to these experiments it would seem, as M. Clausius explains it, that the molecular cohesion of all the permanent gases was zero, and that the deviations from the law of Mariotte, such as we have just witnessed, have their original cause in the material volume of the molecules, their thickness or diameter.

In vapors, on the contrary, cohesion exercises its power, even under slight pressures, and would cause an inverse deviation from that observed in comparing vapors with permanent gases.

It is essentially these phenomena which we wish to investigate more thoroughly; based on the experiments of MM. Regnault and Natterer, and on the theory of M. Clausius, besides using a previous

work on the relations existing between the different physical and chemical properties of volatile liquids.[1]

It is shown in the work quoted, that "for the same temperature, the cohesion of all fluids is the same;" that is, the molecular forces which bind two atoms or two molecules of any liquid together, are equal, if the temperature is the same for all the liquids. This theorem may be expressed in the following manner: if we take all the volatile liquids at one and the same temperature, and calculate the work required to tear an atom, α, from any liquid, at this temperature, and to free it from the force of cohesion which holds it, the work expended will be the same for all liquids, without exception.

This law proves that the fluid state does not manifest itself indistinctly, however great may be the force of cohesion. This cohesion must represent a certain force, K, operating at a distance, l, between two molecules, in such a manner, that the work of condensation or evaporation corresponds to that constant quantity for a temperature, t. Without this essential condition, liquefaction would be inexplicable.

The only known force which directly opposes cohesion is heat. It is admitted that it imparts to the constituent elements of bodies vibratory oscillations, whose amplitude is a function of the temperature.

A number of conclusions, drawn principally from the variations in the latent heat, such as are furnished by the tables of M. Regnault; laws which link the tension of the vapors to the temperature; the laws of expansion, etc., etc., lead me to advance the hypothesis: that the temperature, following a simple function, is directly proportional to the amplitude of the calorific vibration.

Taking a very small fraction of the millimetre as a unit, similar to that used in measuring the undulations of light, it would be found that an oscillation of a double amplitude would correspond to double the absolute temperature; an oscillation of triple the amplitude would give a temperature three times higher. Absolute zero would correspond to a length of oscillation equal to zero; as, for instance, a pendulum that had been arrested.

This definition of temperature agrees with what we previously asserted.[ii] It consists in assuming that the temperature of a body is absolutely determined, if the dynamic potential of the same, between

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[1] *Archives des Sciences, phys. et nat.*, Jan. 1876, t. LV, p. 66.

[ii] Société de physique et d'histoire naturelle de Genêve Séance de Jeudi, 20 Décembre, 1877.

any temperature t' taken as a starting point, and a variable temperature t, always given by the dynamic equation into which it enters, be known.

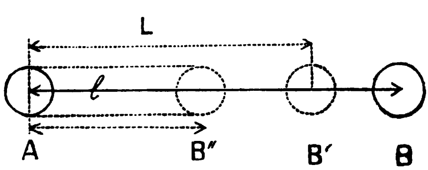
The computation of the tension of the vapor of water, based on this theory, agrees, within one mm., for all temperatures between 200° and 0°. We therefore think that we can adopt this equation as probably correct, and consider it as the measure of the amplitude of the calorific motion.

Does this imply that when a body has a temperature of $t°$, all the particles of the same, without exception, will vibrate in such a manner, that the amplitudes are all exactly equal? By no means. On the contrary, certain vibrations interfere with each other and produce sometimes longer, sometimes shorter, vibrations. The temperature of the body will correspond to the mean of all these elementary motions, and will represent the dynamic resultant of all the individual forces which constitute the store of work accumulated in this body; which store we call its potential.

This manner of explaining the action of heat can be demonstrated experimentally, by the change of state, of liquids into vapors, and *vice versa*.

Let us take any vapor under a pressure P, and at a temperature t. Under these conditions the inter-molecular interval which separates the free molecules of vapor, is inversely proportional to the number of these molecules. For double the number, the interval will be one-half.

Fig. 1.



Let K represent the energy of cohesion at the temperature t, a constant for all liquids; and let l be the amplitude of the calorific oscillation, corresponding to the temperature t. The annexed cut represents two molecules of this vapor, taken at the pressure P, and at the temperature t. The distance of the molecules A and B apart is $A\ B$, and this distance may be varied at pleasure by increasing the pressure of the gas. Let L be the minimum distance through which the cohesion has sufficient energy to obtain the value K, and let $A\ B''$ be equal to l, the length of a calorific oscillation corresponding to the temperature t. We can now trace the phenomena which will occur, step by step.

It is evident at once that "cohesion cannot produce liquefaction" as long as the tension keeps the molecules A and B at the distance $A\,B$ from each other, its power being inferior to K, the extreme limit. Consequently the vapor might be compressed, and a new quantity of gaseous elements introduced into the same volume. As soon as the tension has reached a value P', the distance $A\,B$ will be reduced to $A\,B'$. Precisely at this moment, the cohesion having become equal to K, the molecule B would be precipitated on molecule A, and they would form a drop of liquid. The two molecules will develop great heat, as the first oscillation will be equal to $A\,B'$, and a few instants later would be reduced to $A\,B''$. The work expended and transferred to the walls of the receptacle, represents, as "latent heat of condensation," the work of cohesion between the limits $A\,B'$ and $A\,B''$. The difference in volume between the gas and the condensed liquid enables us to determine the ratio $\frac{A\,B'}{A\,B''}$. This change of volume is considerable for liquids of average volatility.

From the above, the simple operation of the law of Mariotte, and the law of molecular cohesion, we can readily explain the manner in which liquefaction of a vapor takes place. It must commence by the molecules approaching each other to within a certain limit, where the cohesion is sufficiently strong; then, from that moment, if the temperature is assumed as constant, the pressure will be so also, whatever may have been the quantity of vapor originally introduced into the same space; the pressure P' will be a maximum. The latent heat disengaged is a function of the distances $A\,B'$ and $A\,B''$, and of the number of molecules condensed. It is consequently also equal to a value of K, corresponding to the temperature of condensation, $t°$.

We should find the explanation of all the phenomena connected with the change from a gaseous to a liquid state, if we successively examine all known vapors under the same conditions. Let us make this examination, chosing the fluids according to their volatility.

It will be admitted that the force with which two molecules attract each other, varies with the nature of the body. The less volatile a body, the higher its boiling point on the thermometric scale, the greater is the tendency of cohesion to reunite its constituent particles. We may also conclude that the distance at which the molecules of this body will attract each other at a temperature t, will be greater than the corresponding distance, under the same conditions, for two molecules of a more volatile liquid.

Let us take water and sulphuric ether, for instance, and compress their vapors at a temperature of 30°. The distance $A\,B'$ for water will be greater than that of ether; consequently, according to the law of Mariotte, the tension of the vapor of water will not be as great as that of the vapor of ether. The pressures will be directly proportional to their volatility. The distance $A\,B'$ corresponds to 31·548 millimetres of mercury for water, and to 634·80 for ether.

The tension is not the same for both liquids; however, the length of the calorific oscillation $A\,B''$ will be the same for both fluids after condensation. The latent heat disengaged, in both cases, will, therefore, be solely proportional to the number of molecules which will have transformed themselves into liquid, by means of cohesion, to a constant, K, dependent on the temperature, and to a function which gives the increase in the power of cohesion, with reference to the distances which separate the molecules A and B.

Comparing water successively with sulphuric ether, sulphurous acid, ammonia and carbonic acid, we see that the distance $A\,B'$, at which condensation takes place, diminishes more and more, the more volatile the liquid we choose. At 0°, water condenses at a pressure of 4 millimetres, sulphurous acid requires 1165, methylic acid, 1879, and, finally, carbonic acid requires almost 30 atmospheres.

It is evident that the more refractory a vapor, regarding condensation, we choose, the less will be the difference between the volume of condensed liquid and that of the vapor. This is important, as it proves, that the only variable element is the force of cohesion, dependent on the peculiar nature of the vapor.

We see from all that precedes, that two conditions must be fulfilled to accomplish the condensation of two gaseous molecules A and B:

1. To bring the molecules so near to each other that the distance $A\,B'$ may correspond to a minimum attraction equal to K.

2. It is necessary and indispensable that the distance $A\,B'$ should be greater than $A\,B''$, which is the amplitude of the oscillation due to the temperature.

For were the attraction of the gaseous molecules but feeble, and the amplitude of oscillation l corresponding to a temperature t larger than the distance to which the molecules must be brought, so that the force of cohesion may be K, then "liquefaction becomes impossible, as at this temperature t, the minimum length (l) of oscillation is too great to allow a change of condition.

The second condition thoroughly explains all the phenomena relating to the so-called permanent gases. To condense these gases, it does not suffice to subject them to enormous pressures; the amplitude of the calorific oscillation must be brought below AB'; and to do that, their temperature must be lowered, their heat abstracted so as to reduce their calorific motion to a minimum. $A\,B''$ then being very small, as small as possible, we may hope that the distance $A\,B'$, at which the cohesion reaches the value K, will be larger than AB'' "Only under these conditions" is liquefaction obtainable. Up to the present time it has been believed that pressure and temperature were so allied that the one might always be substituted for the other. This is true within certain limits, which we have defined by this explanation.

It is possible to determine tables of the tension of the saturated vapors of almost all volatile liquids. These tables show the relation which exists between the increase of pressure and the temperature t. But they cannot possibly be determined for very high values of t; and experience has shown that at a certain temperature t, the liquid passes spontaneously into a vapor, without change of volume. Starting from this point, the liquefaction of vapors generated in this manner becomes impossible. For water this temperature is between 400 and 500 degrees; for ether it is lower; for sulphuric acid it does not reach 250°; for carbonic acid and the protoxide of nitrogen it is even lower; finally, for the permanent gases, hydrogen, oxygen and nitrogen, this point is below the usual surrounding temperature.

This explanation will now permit us to consider the law of cohesion as universal, and proves that in order to liquefy these gases, the indicated means are indispensable:

To employ a great pressure. To employ great cold.

These two aids are necessary, should be employed simultaneously, and can be replaced by no expedients.

The analytical discussion which has conducted us to this result will admit of numerous applications. All the laws which govern the changes of internal, latent and external heat, the tension of volatile vapors, the specific heat, mixtures of gases and vapors; in a word, all calorimetry and thermodynamics are included in the problem we have just investigated.

All these special applications will be found in a pamphlet now in course of preparation. Here we merely wish to demonstrate, experimentally, that the preceding deductions, concerning the permanent gases, are correct.

ON THE EROSIVE AND ABRADING POWER OF WATER UPON THE SIDES AND THE BOTTOM OF RIVERS AND CANALS.

By CLEMENS HERSCHEL, Civil and Hydraulic Eng., of Boston.

The title of this paper will recall to the minds of most engineers some well known, but, as will be shown, somewhat too highly valued observations of the " Ci-devant Colonel au Corps Royal du Genie," Le Comte L. G. Nançay Dubuat, who experimented 100 years ago—more exactly, between 1780 and 1784. To some it may also recall the fervent appeals of Mr. Thos. Login, M. Inst. C. E., 1867-69, in behalf of this same and but feebly illuminated branch of engineering and hydraulic science. Compelled to consider the matter, in the course of his professional practice, the writer has drawn freely upon all the German, French, English and American authorities within his reach; and, as showing the great utility and deciding influence which such a study may have in the consideration of water-courses, a concise history of the engineering problem referred to is here given; this is no less than that of the Cape Cod ship canal, in the state of Massachusetts.[1]

The Isthmus of Cape Cod, plainly to be seen on most any map, or globe, even, that represents the United States, is in effect nothing but a huge mole, or pier—a sort of fence run out into the sea, that separates the "Bay shore" of Massachusetts, and the sea-coast of Massachusetts, New Hampshire and Maine to the north of that, from the rest of the United States. But this is not all; navigation around this obstruction is of a very hazardous kind, because of the many and concealed shoals all along the route through the sound, and also on the outside of the islands of Martha's Vineyard and Nantucket; and from the fact that there is no harbor, not even for small coasters, between the southerly and the northerly ends of the Cape; further, because the sailing directions around this cape make less than a right angle with each other, because of the rigor of the climate in the winter, on account of the danger of collisions in the narrow channels between the shoals and in fogs, and from other such causes.

[1] See also an article by J. P. Frizell, C. E., JOURNAL OF THE FRANKLIN INSTITUTE, 1871, on the same subject.

These difficulties may be measured by their effects, which comprise wrecks and losses of life and property to a remarkable extent. Thus, from 1843 to 1859, 17 years, there were 827 wrecks, of which a record could be found: 4 steamers, 40 ships, 71 barks, 191 brigs, 492 schooners, and 29 sloops; total losses, 500, partial losses, 327; average of the total losses (compiled from the records of 108 cases), $500,000 annually; average of the partial losses, $81,750 annually; loss of life, estimated at 30 annually.[1] For the ten years succeeding, 1859 to 1869, there were lost 13 steamers, 23 ships, 32 barks, 100 brigs, 446 schooners, and 3 sloops; total, 617 wrecks; total losses, 211, partial, 406. And all this on a length of steamer line of only about 160 miles. And, of course, these losses have their effect on the rates of insurance and the freight charges by vessels that pass the Cape.

It cannot be surprising, therefore, that the project of constructing a canal across the Cape should have frequently been spoken of, and, in fact, we find that ever since 1623, only three years after the settlement of the country by the prilgrims of Plymouth, the utility of going through or over the Cape, rather than going around it, seems to have been recognized, and that a canal has been contemplated for more than 200 years. It will not be necessary to give in this place a history of all the attempts that have been made to commence the construction of such a canal by public, as well as by private, means. Suffice it to say that 8 distinct efforts of this kind have been made, the last of these having been made in 1860. And now, lest any one will have found the explanation of this remarkable state of affairs in the topography of the country through which the canal is to pass, it will be proper to state at once that this topography is of the most favorable description. There is a valley running through the Cape at its narrowest part, precisely where it joins the mainland, at the head of "Buzzard's Bay," and where the distance from bay to bay, on line of this valley, is about seven miles and a half. The bottom, or intervale, of this valley, is some 600 ft. wide at its narrowest part, and is, in maximo, about 32 ft. above the controlling mean low water of the sea. The meaning of this phrase, "controlling" mean low water, being, that low tide in one bay is at a different elevation from what it is at the other, and the lowest low water is naturally

[1] From the report of the Legislative Committee of 1864. Some wrecks are included which should have been omitted; others were, no doubt, omitted, of which no record had been kept.

the "controlling" low water. The average depth of cutting, for a canal 18 ft. deep at controlling mean low water, would be only about 35 ft. The material, as shown by borings to the proper depth, and from all the other information that can be reached, is, throughout, nothing but mud, sand, gravel, and a few boulders. Two tidal creeks occupy this valley, and their head-waters nearly overlap each other. Every report that has ever been made upon this project has spoken of it in highly favorable terms, and has estimated that the enterprise would be a profitable one, viewed from a national and political-economical standpoint. Why, then, has this canal never been built? Why has it not been built since 1860-64, date of the last investigation upon the subject by the state of Massachusetts?

Of course, the answer to these questions may be variously enunciated, but a tolerably fair one to the last of the two questions may be given, though it seems almost laughable to say so, by reference to only these two sentences in the report of 1864: "We have already spoken of the locks required, in consequence of the different levels of the sea at the two extremities of the canal. The mean of the daily maximum variations in the elevations of the two basins" (occurring 4 times in the 25 hours) "is 6·5 ft." (should have been 5·23 ft.); "and such a fall in the distance of eight miles, must, we need not say, be kept under control." Further than by these words, the *question*, whether or not locks were a necessary part of the plan, was nowhere discussed, but it was *assumed*, as by the last phrase in the second sentence above quoted, that canal locks were unavoidable. But the same report takes care to say that the current to be produced in the canal will not be detrimental to navigation; it "would not exceed from three to four miles per hour; it sometimes reaches nearly three miles per hour off West Chop, where the tide-waves cross each other in eleven fathoms of water." The report quoted from is a preliminary report, made by an "advisory council," and the inference is irresistible that the only reason that the advisory council assumed the necessity of, and recommended, locks, and all the evils that these entail, was on account of the supposed destructive effects which those currents were going to have upon the sides and bed of the canal. Subsequent engineers made the same assumption, and the fears so engendered have remained alive to the present day; so that it is yet impossible to speak of the Cape Cod ship canal to any merchant or other otherwise intelligent person in Massachusetts, without hearing

it answered, that owing to the necessity of locks, breakwaters, etc., the cost of such a canal would be something quite tremendous and altogether impracticable.

This leads to the consideration of what have above been referred to as the evils entailed by the plan of having locks, or a lock at either end of the canal. First, as regards an increase of cost: 1. The cost of the locks themselves, which, to accommodate, as they would have to at the present day, some 40,000 vessels per annum, would have to be built in triplicate and quadruplicate form, and, from their size, would cost large sums of money to build and to operate. 2. Since the locks at the northern end would stand upon an open seashore, on a sandy beach, they would require highly expensive works for their protection, and for the protection of vessels about to use them. It will not be necessary to enlarge upon either of these points, as they will be sufficiently appreciated by all engineers of the present day. Suffice it to say that the estimates for the two kinds of canal—the one an open cut, with jetties at the northern end to lead to deep water, the other with locks and breakwaters and jetties—compare about as 1 to 4; that is, as 2 millions of dollars to 8 millions. Secondly, comparing the two plans as to their probable income: 1. The canal is most needed in the winter, that being the most dangerous season of the year for navigation, when many coasters absolutely decline to take freights from New York, and further south, for Boston, and further north. But it is precisely then when a canal with locks would be out of service, being frozen up. On the other hand, there are good reasons, which need not now be gone into, for believing that an open cut, a "cut-off," speaking after the manner of river engineering as applied to tidal waters, would remain open all the time, especially when used by steam navigation. 2. Less detention and danger to vessels in passing through an open channel, than in passing through locks; hence greater use of the canal in the one case than in the other. 3. Less cost of haulage, or of steaming through the canal in the first case than in the second. A vessel could drift through with the tide in about three hours, and could drift either way twice every 25 hours; and naturally this drift of the current would work to the advantage of the steamer quite as much as it would to that of the sailing vessel. So that taking it altogether, it is within the mark to say that the plan with locks is simply out of question as a remunerative enterprise. Where the first would be a highly profitable

investment for private capital, the other may reasonably be shunned by even a paternal form of government; and has been shunned and has rested *in terrorem* in the minds of those interested for the past fifteen to seventeen years, ever since that unfortunate dictum—"such a fall must, we need not say, be kept under control"—and its resultant plans and estimates, and report of 1864.

To complete this sketch, and before examining the hydraulic question given in the title of this paper, it will be well to give, in concise form, the heights of tide that obtain at either end of the proposed canal, as carefully determined by observations of Henry Mitchell, the present Chief of Hydrography of the U. S. Coast Survey, in 1860-62. The table below will be all that is necessary; the heights read above (+) and below (—) the mean level of the sea, which is the same at both ends of the canal. This level is called grade 52·7 in the report.

The channel or preliminary cutting for which the velocities given in the table have been computed, for several times of the tide, has its bed about 20 ft. below the mean level of the sea at the southern end, and about 22·5 ft. below it at the northern end. It is 66 ft. wide at the bottom, and has temporary side slopes of 1·25 on 1, making the water-line from 111 to 134 ft. wide. The velocities given have been computed by Hagen's formula for *large rivers and canals*, this formula having been selected on account of its great convenience in use, and simplicity, while it remains, at the same time, a very reliable formula for large rivers and canals; but those who may prefer any other formula will readily see that the present is not one of those cases where a difference of ten and of even more per cent. in the resultant answer will be of consequence. The average skipper cares very little whether he has to tow against 3·3, or 3·6 or 3·7 knots per hour for a distance of 7·5 miles. The bottom velocities are calculated from the simple rule given by Schlichting, derived from Hagen's formulæ, and exactitude in their case, within about 10, or even 25, per cent., may also be shown to be of no serious import. These formulæ are:

$$\text{Mean Velocity} = 6 \,.\, \sqrt{\frac{\text{Area}}{\text{Wetted perim.}}}\ \sqrt[5]{\frac{\text{Fall}}{\text{Length}}},\quad \frac{\text{Mean Velocity}}{\text{Surface Velocity}} = 1 - 0{\cdot}0326\ \sqrt{\text{Depth}};$$

and Bottom $V.$ = 3 Mean $V.$ — 2 Surface $V.$

If this sketch has served to give a rude description of the locality and canal, during the study of which the materials for the balance of

SIMULTANEOUS TIDAL OBSERVATIONS AT TERMINI OF PROPOSED CAPE COD CANAL, AUG. 14, 15, 1860, AND COMPUTED CURRENTS THROUGH CANAL.

Hour.	Height of tide in ft. at the northerly terminus.	Height of tide in ft. at the southerly terminus.	Fall in ft. on a length of about 40,000 ft.	Direction of current	REMARKS.	CURRENTS. Mean Velocity. Feet per second.	Surface Vel. Feet per second.	Surface Vel. Miles per hour.	At bot. and sides. Feet per sec.
0	—1·2	—1·6	0·4	S.	Nearly highest spring tides.				
1	—3·2	—1·0	2·2	N.	Fall = 0 at 0 h. 10 m.				
2	—4·7	—0·6	4·1	N.	L. W. northern end, at 2 h. 25 m., when fall = 4·5.				
3	—4·5	—0·0	4·5	N.					
4	—3·7	+1·1	4·8	N.		3·7	4·3	2·9	2·5
5	—2·2	+1·55	3·75	N.	H. W. southern end.				
6	—0·45	+1·35	1·8	N.	Fall = 0 at 6 h. 50 m.				
7	+1·2	+0·8	0·4	S.					
8	+3·0	—0·2	3·2	S.	See Note.	[4·3]	[5·0]	[3·3]	[2·7]
9	+3·7	—1·2	4·9	S.	H. W. northern end.				
10	+2·9	—2·1	5·1	S.					
11	+1·4	—2·3	3·7	S.	L. W. southern end.				
12	0·0	—1·6	1·6	S.					
13	—1·95	—1·05	0·9	N.	Fall = 0 at 12 h. 35 m.	2·5	3·0	2·0	1·7
14	—3·75	—0·4	3·35	N.		3·3	3·8	2·6	2·2
15	—4·3	+0·4	4·7	N.	L. W. northern end.				
16	—3·3	+1·6	4·9	N.		3·7	4·3	2·9	2·5
17	—1·4	+2·4	3·8	N.	H. W. southern end at 17 h. 40 m.				
18	+0·7	+2·6	1·9	N.					
19	+2·8	+1·9	0·9	S.	Fall = 0 at 18 h. 45 m.	2·8	3·3	2·2	1·8
20	+4·5	+0·5	4·0	S.		3·7	4·4	2·9	2·4
21	+5·5	—0·8	6·3	S.	H. W. northern end.	4·1	4·8	3·2	2·6
22	+4·9	—1·7	6·6	S.	Max. fall = 6·7 at 21 h. 40 m.				
23	+3·1	—2·1	5·2	S.	L. W. southern end at 23 h. 20 m.				
0	+1·3	—2·0	3·3	S.					
1	—1·1	—1·8	0·7	S.	Fall = 0 at 1 h. 10 m.				

Mean fall in 25 hours = 3·43 ft. [irrespective of direction].

NOTE.—Calculated for a fall of 3 ft. and full canal—an extreme case.

this paper were gathered, and has served to show at least one instance where the application of such study would seem to be of decided and decisive character, it will be proper to proceed now with the consideration of the purely engineering question of the determination of the effect of running water upon the sides and the bottom of rivers and canals.

The way that has usually been followed in this particular species of investigations, hitherto, has been to find formulæ derived from series of experiments that give, from the cross-section and slope of any channel, its mean velocity; then another set that enable the surface and the bottom velocities to be arrived at; then find by experiment the effect of certain velocities on certain substances, generally in very small quantities, and resting upon smooth horizontal plank; upon which, nothing so plain, but that such and such slopes of water will carry away such and such banks and beds of the channel. It affords a healthy check, however, on these conclusions, to compare them with what we see going on around us, of this sort of action, both in rivers and in artificial channels; also not to stop the investigation with the mere *starting* of the kinds of channel surface under discussion, but to pursue the investigation a little further, and see what will take place next, and to consider the extent of such action; for, although a canal in embankment might be endangered by such operations, another, entirely in excavation, may be greatly improved by the same scouring process.

The present paper does not pretend to solve, however imperfectly, the question here presented; this could, of course, only be done in the light of extensive and well conducted experiments. Many investigators are at work in solving the problem of velocities of rivers and canals, and the distribution of velocities in any cross-section, and in that part of the general question we may, sooner or later, feel that we are standing on an unassailable foundation of knowledge, at least in the case of perfectly regular channels. In the meantime, and in default of any very decisive experiments made as yet upon the actual effect of large streams or canals upon their beds, the best immediately attainable results are those that may be derived from a compilation of such data as are recorded in engineering literature. To do this has been the essay of the following pages.

Engineering literature on the erosive or abrading power of water may be divided into three classes: 1. Experiments on the effect of

running water upon substances of various sizes and weight in artificial channels. 2. Facts to be observed in natural streams. 3. Discussions of the facts derived under the heads just cited. As some writers have done service in all three of these methods, the division will not always be followed out, but it is well enough to have it thus stated at the outset, for a better understanding of the whole subject.

Dubuat[1] [1780-84] seems to have been the first writer on the effect of currents upon the bed of the channel, who gave facts and figures, and is quoted to this day more frequently than any other experimenter. In the course of the 91 years that have elapsed since the first appearance of his book, his remarks have been translated and quoted back and forth so many times, that their original import, and weight as testimony, are hardly discernible, and it is very instructive to refer back to just what Dubuat said on the subject matter of this paper, and to consider his description of the experiments made by him.

Dubuat thought that he had found a constant relation between the mean, surface and bottom velocities of any stream, and that this was expressed by the formulæ:

$$V_D = \left[\sqrt{V_0} - 1\right]^2; \text{ and } V_m = \frac{V_0 + V_D}{2},$$

using the Humphrey-Abbott notation, where V_m, V_0 and V_D represent the mean, surface and bottom velocities (Sec. 66, Dubuat). These are the formulæ used by Beardmore in his Manual of Hydrology, to compute Table 3. It is high time, however, to acknowledge and recognize that these formulæ are nothing but a first approximation, and that they are deserving of no especial confidence at the present day.

Dubuat used in his experiments two rather diminutive troughs made of plank (see the plate in Vol. 2), one rectangular in section, and about 18 in. × 12 in., inside measurement; the other trapezoidal in section, about 6 in. wide at the bottom, side slopes about 1⅜ on 1, and water about 8 or 10 in. deep; their length is not given. Dubuat only says he should have *liked* to have made them 500 or 600 ft. long. Besides this he made 6 experiments on a canal varying from about

[1] "Principes d'Hydraulique et de Pyrodynamique." Nouvelle edition. 3 vols. Paris, Firmin Didot, 1816. (First edition appeared in 1786.)

48 to 127 sq. ft. in section, and 4 experiments on a small river, varying from about 241 to 310 sq. ft. in section; both very shallow, only about 1 to 2 to 3 ft. deep, and 3 of these were rendered unreliable by untoward circumstances, as detailed by Dubuat himself. Nevertheless, these spoiled experiments, and the others, are to this day occasionally used by the constructor of hydraulic formulæ. All the experiments were conducted in a tolerably crude manner, looking at them in the light of the much more carefully and exactly conducted ones of later times, the velocities being generally measured by little wooden and other floats (gooseberries for measuring bottom velocities), levels taken by measuring down from pegs, etc., so that, taken altogether, if the whole of Dubuat's experiments were dropped out of all future consideration, it would no longer be a serious loss to science; indeed, to consider them, and give them the same weight with many more perfectly derived ones of later days, in the study or derivation of formulæ, they cannot but be looked upon as decidedly unscientific, and resembling, in some degree, that celebrated "survey" of the American humorist, John Phœnix, Esq., who averaged the distance as given between two places, by a peculiar sort of triangulation, of astronomical observation, and of direct chaining, and by casual estimate of a bystander, as the best result attainable.[1]

The same little troughs mentioned above, served for the experiments on the "abrading and transporting power of water," the *rolling* along of gooseberries giving the bottom velocities. These results of Dubuat's experiments are best given in the table of Vol. 2, Sec. 399, though they are also stated in words, somewhat incompletely translated, as usually quoted, in Sec. 71 of Vol. 1.

[To be continued.]

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[1] To discuss, as part of the general question, the subject of what is called the "scale of velocities" in currents, and the dependence of the mean or surface velocity upon cross-section and slope, and to bring such discussion to date, would extend this paper to the size of a comprehensive treatise on hydraulics. The writer cannot venture upon this field of labor at this time, and, in place thereof, may leave, without argument, to each engineer the use of such well founded formulæ as seem best to him. That there is no one formula, or no one set of formulæ, that commands universal respect and confidence among engineers, is much to be regretted. Just at present, this matter is in a peculiarly deplorable state, from over-zeal of writers to evolve something new, in the first place, and absolutely exhaustive, in the second, and without due regard to a proper study of the subject, or to the quality of the data which they recklessly throw pell-mell into their formula-producing chaldron.

EXPERIMENTS MADE TO DETERMINE THE INFLUENCE OF TEMPERATURE ON THE DISCHARGE OF WATER FROM AN ORIFICE IN THE HEMISPHERICAL BOTTOM OF AN OPEN TOPPED CYLINDRICAL VESSEL.

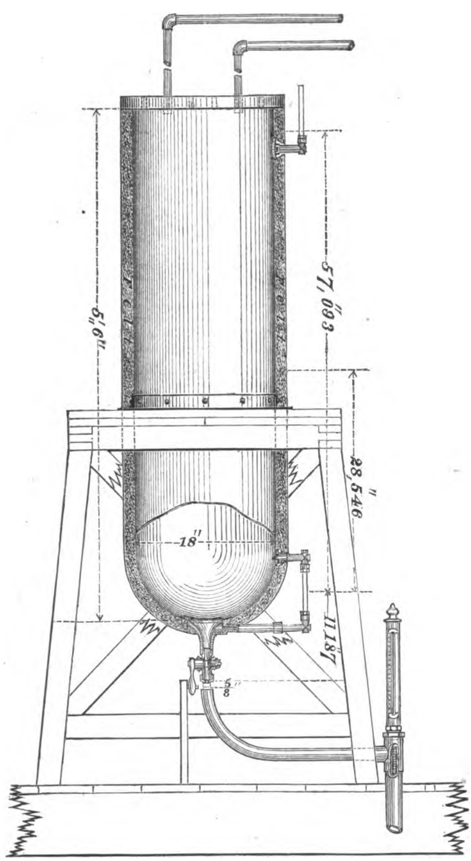
By Chief Engineer ISHERWOOD, U. S. Navy.

That the mobility of water is greatly influenced by its temperature, is a fact obvious on inspection to any discerning eye; but the writer is not aware that any experiments, except those recorded in this paper, have ever been made to determine the comparative value of that influence for the different degrees of the thermometric scale. The importance of this determination in steam engineering is greater than may at first sight be apparent, for not only is the leakage of water from boilers affected by it, but also the resistance of water to motion in pipes, and to the progress of the immersed solids of vessels. The first is of practical consequence in the testing of boilers, the second in all pumping operations, and the last in the propulsion of vessels. It will be seen from the results of these experiments that a boiler which may be tight under a given pressure when tested by the pumps with water of one temperature, may leak when tested under the same pressure with water of a higher temperature; so that a really complete test of boiler tightness requires not only that the pressure shall be equal to the steam-pressure which is to be carried in practice, but that the temperature of the water with which the test is made shall be the same as the temperature normal to this steam-pressure. Again, in pumping operations, it will be seen that the duty of a pumping-engine cannot be accurately calculated for the weight of water raised and the height to which it is elevated alone, because it must have a correction for the influence of the temperature of the water, as the higher that is, the less, in some ratio, will be the resistance the water opposes to the engine. The higher the temperature, the greater is the freedom with which the molecules glide over and around each other, causing the water to deflect more easily along the sinuosities of the pipes, and to receive less resistance from their surfaces. In the propulsion of vessels, the water of higher temperature opposes, for the same reasons, less resistance to their passage than water of lower temperature, even allowing for their greater draught in the warmer water due to its less density.

In the various determinations which have heretofore been made of the ratio of the actual to the theoretical discharge of water through orifices, the temperature of the water should have been noted, as the actual discharges, *ceteris paribus*, are affected by it, while the theoretical discharge remains constant at all temperatures. The experimental ratios are true for only the experimental temperatures, and need reduction to a standard temperature.

Description of the Apparatus.

Fig. 1.

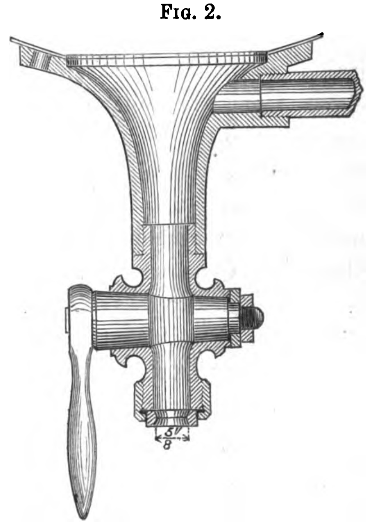


The apparatus, Fig. 1, consisted of a vertical cylinder, 18 inches in external diameter, with an open top and a hemispherical bottom, the whole being 5 ft. 6 in. in height, and made of copper as thin as consistent with rigidity of form. The lower part of the bottom had an aperture of 4 inches diameter, to which was bolted a vertical brass bell-mouth of 4 inches internal diameter at top, and $1\frac{1}{16}$ in. internal diameter at bottom, the sides being formed of converging curves. The bell-mouth was $4\frac{1}{8}$ inches in internal height, and its axis was in the same vertical as that of the cylinder; near its top was a horizontal cylindrical nozzle, into which was screwed a small water-pipe communicating with the lower glass water-gauge. Into the bottom of the bell-mouth an ordinary stop-cock was screwed, having a water-way of 0·77 inch

diameter, to which was adjusted a washer or disc of brass (see Fig. 2), one-fourth of an inch thick, perforated with a hole of five-eighths of an inch least diameter, the sides of this hole were rounded on a semi-circle, and its axis was in the same straight line with the vertical axis of the stop-cock and bell-mouth.

At 1 inch below the washer was placed a pipe of 1¼ inches inner diameter, to receive the water discharged, the column of which was therefore in open view. This pipe was curved laterally, and connected to a vertical drain-pipe of 1½ inches inner diameter, situated 6 inches from the axis of the cylinder. In the vertical pipe was placed a large thermometer with a long bulb, protected by a perforated casing of brass. The bulb was opposite and below the junction of the two pipes, so that the water discharged flowed freely over it. The apparatus was supported upon a stout wooden framing, by means of a brass flange, riveted to the cylinder. Attached to the side of the cylinder were two glass water-gauges, having their vertical axes in the same straight line, one near the top, and the other near the bottom.

Fig. 2.



The open top of the cylinder had a wooden cover, part of which was screwed fast to the cylinder, and had passing through it two pipes, one leading to the water space of a steam boiler in use, and the other to the water of the Croton aqueduct. Both pipes were fitted with suitable stop-valves, and by their means the cylinder could be filled with water of any temperature between 32° and 212° Fahr. The remaining part of the cover was removable, and was perforated with a number of small holes, to allow the escape of the steam when the valve in the hot-water pipe—or pipe connecting with the boiler—was open.

The entire cylinder and its hemispherical bottom were closely covered with felt 1½ inches in thickness.

The apparatus was erected in the engine-room of the boiler-shop of the "Novelty Iron Works" in the city of New York, and all its

appendages being complete and found perfectly tight, the cylinder was nearly filled with water, and a permanent mark made at its level on the upper glass water-gauge. Eight and one-half cubic feet of water were then measured out of the vessel, drawing it off into a box of exactly one cubic foot capacity, made especially for the purpose; this brought the water-level to a convenient point for observation in the lower glass water-gauge, which point was permanently marked on the lower gauge in a similar manner to the upper one.

Manner of making the Experiments.

In commencing an experiment, the cylinder was filled to a few inches above the mark on the upper glass water-gauge, with water, either from the boiler or from the Croton aqueduct, or from both, according to the temperature desired. In the latter case, the water was let in simultaneously from both pipes, so as to mix as the cylinder filled, and the mixing was made more thorough by stirring the water in the cylinder with a board having a surface on one side of about half a square foot. This board was fitted with a long handle at right angles to its surface. As soon as the water became quiescent the discharge-cock was opened, and the exact times were noted when the water-level was at the mark on the upper glass water-gauge, and at the mark on the lower glass water-gauge. During the discharge of the water between the marks on the gauges, the thermometer was noted every minute, and the mean of the observations taken for the temperature of the water. As the cylinder was filled about 2 inches above the upper mark, the water had sufficient time to acquire its velocity in descending to that mark, independently of the time consumed in opening the discharge-cock. It will be observed that the area of the water-way through the plug of this cock was nearly one and a half times the area of the discharge-orifice through the washer; therefore, no small difference in the opening of the cock could influence the freedom of the discharge; but, to prevent any question, a stop was properly fixed, so that the handle of the cock always opened against it. The discharge orifice was not changed during the experiments; and the column of water issuing from it being in full view, any accidental obstruction, had any occurred, would have been immediately detected. The water entered the lateral pipe in the form of a smooth cylinder, except at the highest temperatures, and losing there the

greater part of its velocity, flowed around the bulb of the thermometer, and passed into the drain-pipe. During a portion of the experiments the time was noted by a stop-watch, but it was found that by holding a common watch in such manner as to bring the second hand close to the marks on the glass water-gauges, the eye could note the time fully as quickly and as accurately as the thumb could press the spring of the stop-watch. When filling the cylinder with a mixture of hot and cold water, both were allowed to run in at the same time, and the equality of the temperature of the mass was assured. By carefully observing this simple process, the temperature, when low, of the discharging water, would not vary over a degree, and when high, not over four or five degrees between extremes. The temperature of the water from the Croton aqueduct was, for most of the time, about 37 degrees Fahrenheit, and for experiments with lower temperatures it was reduced by ice, in which cases the water was thoroughly stirred and the unmelted lumps of ice skimmed off before opening the discharge-cock. The water used in the boiler was also from the Croton aqueduct.

The experiments were two hundred and forty-six in number. They occupied many days, and were about equally distributed between the temperatures of 32 degrees and 212 degrees Fahrenheit. From their corrected results the following table was formed by laying off by scale, on a straight line, the observed temperatures as abscissæ, and erecting at right angles to this line, as ordinates, the corresponding times by scale of discharge, drawing as nearly as possible, through the free ends of the latter, a fair curve, leaving as many points on one side of it as on the other. From the graphic curve thus obtained, the times in seconds of the discharges of the eight and a half cubic feet of water of every degree of temperature on Fahrenheit's scale, from 32° to 212°, were accurately measured off by scale. These times, for every fourth degree, will be found in the second column of the table, and are, of course, for *equal volumes*. In the fourth column of the table will be found the times in seconds of the discharges of *equal weights* of water of the temperatures in the first column, taking the weight to be that due to the eight and a half cubic feet at the temperature of 39° Fahrenheit; these quantities are derived from those in the second column by modifying the latter according to Kopp's determination of the relative volumes of an equal weight of water at different temperatures.

Table

Exhibiting the Results of Experiments made for the Purpose of Determining the Effect of Temperature on the Discharge of Water from an Orifice in the Hemispherical Bottom of an Open Topped Cylindrical Vessel.

Temperature in degrees Fahrenheit.	Time of Discharge in Seconds.				Relative Velocities of Discharge.	
	For equal volumes.		For equal weights.			
	Absolute.	Relative.	Absolute.	Relative.	For equal volumes.	For equal weights.
32	848·25	1·0000	848·3425	1·0000	1·0000	1·0000
36	847·20	0·9988	847·2169	0·9987	1·0012	1·0013
40	845·95	0·9973	845·9517	0·9972	1·0027	1·0028
44	844·80	0·9959	844.8448	0·9959	1·0041	1·0041
48	843·55	0·9944	843·6942	0·9945	1·0056	1·0055
52	842·15	0·9928	842·4473	0·9930	1·0072	1·0070
56	840·85	0·9913	841·3520	0·9917	1·0087	1·0084
60	839·40	0·9896	840·1563	0·9903	1·0105	1·0097
64	837·85	0·9877	838·9074	0·9889	1·0124	1·0112
68	836·30	0·9859	837·7050	0·9875	1·0143	1·0127
72	834·70	0·9840	836·4954	0·9860	1·0163	1·0143
76	833·10	0·9821	835·3285	0·9846	1·0182	1·0158
80	831·50	0·9802	834·2015	0·9833	1·0202	1·0170
84	829·70	0·9781	832·9126	0·9818	1·0224	1·0186
88	827·95	0·9761	831·7105	0·9804	1·0245	1·0200
92	826·20	0·9740	830·5441	0·9790	1·0267	1·0213
96	824·35	0·9718	829·3118	0·9775	1·0290	1·0230
100	822·50	0·9696	828·1111	0·9761	1·0313	1·0245
104	820·65	0·9675	826·9427	0·9748	1·0336	1·0258
108	818·75	0·9652	825·7536	0·9734	1·0360	1·0273
112	816·85	0·9630	824·5929	0·9720	1·0384	1·0288
116	814·85	0·9606	823·3587	0·9705	1·0410	1·0304
120	812·90	0·9583	822·2012	0·9691	1·0435	1·0319
124	810·85	0·9559	820·9678	0·9677	1·0461	1·0330
128	808·75	0·9534	819·7086	0·9662	1·0489	1·0350
132	806·60	0·9509	818·4207	0·9646	1·0516	1·0367
136	804·40	0·9483	817·1031	0·9631	1·0545	1·0383
140	802·20	0·9457	815·8069	0·9616	1·0577	1·0399
144	799·90	0·9430	814·4286	0·9600	1·0604	1·0416
148	797·70	0·9404	813·1706	0·9585	1·0633	1·0434
152	795·30	0·9376	811·7269	0·9568	1·0665	1·0451
156	792·90	0·9347	810·3002	0·9551	1·0698	1·0469
160	790·40	0·9318	808·7863	0·9534	1·0732	1·0489
164	787·80	0·9287	807·1838	0·9515	1·0767	1·0509
168	785·10	0·9255	805·4953	0·9495	1·0804	1·0532
172	782·30	0·9222	803·7147	0·9474	1·0843	1·0555
176	779·60	0·9191	802·0494	0·9454	1·0880	1·0577
180	776·70	0·9156	800·1990	0·9432	1·0922	1·0604
184	773·70	0·9121	798·2356	0·9409	1·0963	1·0628
188	770·80	0·9087	796·3944	0·9388	1·1005	1·0652
192	767·75	0·9051	794·4070	0·9365	1·1048	1·0678
196	764·50	0·9012	792·2200	0·9338	1·1096	1·0708
200	761·30	0·8975	790·0916	0·9313	1·1141	1·0736
204	757·90	0·8935	787·7605	0·9286	1·1192	1·0769
208	754·50	0·8895	785·4345	0·9258	1·1241	1·0801
212	751·10	0·8855	783·1134	0·9231	1·1293	1·0833

The experimental results were corrected for the varying area of the discharge aperture according to the temperature of the water passing through it; the mean linear dilatation of the brass for each degree Fahrenheit, between the temperatures of 32° and 212° Fahrenheit, being taken at 0·00001052 of the length at 32°.

These experiments were made in 1863, and the writer's duties at that time, as Chief of the Bureau of Steam Engineering in the Navy Department, preventing him from giving them his personal attention, they were very carefully and skilfully conducted for him, after the apparatus was constructed, and the manner of experimenting arranged, by Mr. Charles E. Emery, then an engineer in the United States Navy, from whose tabular records or logs of the experiments the writer, after making the corrections above stated, protracted the graphic curve representing their results, and from it constructed the foregoing table. The headings of the columns in this table are so descriptive of their contents as to need no further elucidation.

A remarkable result of these experiments is that the relative velocities of discharge for equal weights of water at different temperatures, are in the ratio of the squares of the relative volumes of equal weights of water at the same temperatures.

FALL OF A HYDRAULIC ELEVATOR AT THE GRAND HOTEL IN PARIS, FRANCE.

By W. Barnet Le Van.

On Sunday morning, February 24th, 1878, the car of the hydraulic elevator of the Grand Hotel being at the second floor, two passengers and the conductor entered it, for the purpose of descending to the first floor.

The conductor started the car to lower, but, instead of descending, the car began to ascend with an alarming rapidity. The casting which connected the piston to the bottom of the car had parted. The car, in ascending to the second floor, was lifted by the pressure of the water under the piston, as usual, but on the opening of the

valve, to let the water flow out from beneath the piston, the reaction of the heavy piston commencing to fall, with the water and the counter-weights acting to pull the car upwards, broke the casting that connected the car with the piston.

The piston immediately commenced to descend in its cylinder, while the counter-weights—now greatly exceeding the weight of the car and its occupants—began to run down and pull the car up at a rapid rate, bringing the top of the car in violent contact with the cross-beams overhead for supporting the pulleys carrying the chains of the counter-weights. The shock was so great that the chains parted, and the car descended by the force of gravity, rapidly increasing from second to second, until it reached the basement, a distance of twenty metres, or sixty-five feet (exactly 65·618 ft.). The weights also fell, and the concussion produced caused a loud report.

On opening the car, the three occupants were found dead. The bodies of the unfortunate persons presented no trace of external or internal injury, except a few drops of blood from the ear of one and the mouth of the others, showing that congestion of the brain had taken place.

The accident was due to a honey-combed casting, which did not show until after the accident. Every precaution had been taken by the management of the hotel to avoid accidents, so far as it was possible to foresee them.

The elevator had only been in use eighteen months, having replacd a former one.

Description of the Elevator.

The lift, or elevator, consisted of a cast-iron cylinder placed in a well the depth of the required lift, in this case it being about seventy feet. In this cylinder was placed a ram or piston, accurately turned. On the top of the cylinder was placed a stuffing-box, so as to securely pack the ram, and prevent leakage of the water used to operate it. On top of and connected to the ram by a casting, was placed the car for passengers. On the side of the cylinder, below the stuffing-box, was an inlet, to which was attached a three-way valve, which was also connected to a cistern placed on top of the building. This valve was operated by a lever, the end of which was connected to a

rod passing through the car to the top of the elevator, thus enabling the conductor to control the movements of the car.

When the lever was in a horizontal position, all communications to the cylinder were closed. On raising the lever the water flowed into the cylinder, causing the ram to ascend at a speed due to the head of water in the cistern at the top of the house; and by lowering the lever from a horizontal position, the connection from the cistern was shut off, and the cylinder was put in communication with the waste-pipe, which allowed the ram to descend. The weight of the ram and car was nearly balanced by two weights, connected to the car by chains which passed over two pulleys placed on the top of the lift. The water in the cistern had only to lift the difference between the weight of the car and piston and that of the counter-weights and load the car was to carry.

The point of fracture was immediately under the car, being the cast-iron connection between the car and ram; and it was found, on examination after the accident, to be due to the casting being of an imperfect porous structure—what is technically termed honey-combed.

From all I can learn, the elevator was not provided with safety catches, such as are used with elevators in this country, and the use of chains to suspend the counter-weights is questionable, as they do not run as smoothly as wire cords, and are more likely to break.

According to the laws of falling bodies, the car reached the basement from the top of the hotel in two seconds:

$$T = \sqrt{\frac{2H}{g}}$$

T = time of fall in seconds.
H = height, in feet, fallen through in the time T.
g = acceleratrix = 32·17.

$$T = \sqrt{\frac{65{\cdot}6 \times 2}{32{\cdot}17}} = 2{\cdot}02 \text{ seconds.}$$

Allowing one second for the time the car took to reach the top of the building, the whole time of the accident did not exceed three seconds.

EXAMINATION OF THE PHONOGRAPH RECORD UNDER THE MICROSCOPE.[1]

By Persifor Frazer, Jr., A. M.

At a meeting of the Philosophical Society, held April 5th, 1878, I described the results of some examinations of the tin foil which had been indented by the stylus, or needle point, of the phonograph.

My object was to ascertain the shapes of the indentations made by different known sounds. For this purpose, Dr. Plush, the superintendent of the Philadelphia Local Telegraph Co , kindly offered his assistance. The vowels and diphthongs were spoken into the mouthpiece of the apparatus with small panels in the order seen on the diagram.

These sounds were repeated thrice on each of three foils. They were then mounted on glass plates, separated, and labeled. Finally, at the suggestion of Mr. Knight, they were cut out and mounted on another piece of glass vertically, instead of horizontally, in order that a number of the dents produced by any given sound might be on the screen at once. I am much indebted to Mr. Holman for his kindness in adapting the apparatus, which he himself will explain a little later to the purpose of showing these phonographic records.

Lissajous, Leon Scott and König have provided the means of transforming sounds into form, in various ways, viz.: By bright points on the ends of steel bars of different thicknesses; by vibrating membranes at the extremity of a "phonautograph," and by flames reflected in a rotating mirror. It was natural to conclude that the same vibrations, imparted to a steel point by means of a metal diaphragm, would leave an equally characteristic trace.

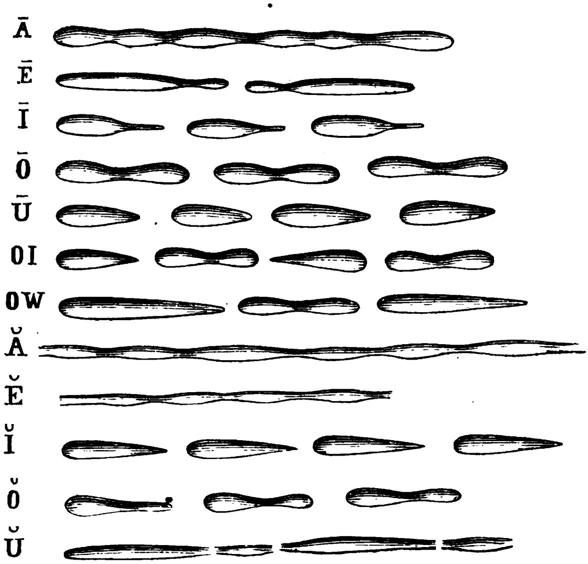
It was intended to take a solid cast of these depressions in Canada balsam, or some other transparent substance, and then reproduce, in the mind's eye, the path of the stylus point. There has not been time for this.

The same voice (that of Dr. Plush), speaking the following vowels and diphthongs as nearly as possible at the same distance from the mouthpiece, was relied upon for the matrices.

[1] Presented at the meeting of the Franklin Institute, April 17th, 1878.

The first records tried, to ascertain whether the pronunciation was perfect, were afterwards thrown away, and the records which were studied were not in any way injured by a second passage of the point of the stylus.

By following along the nearly vertical line of impressions, which are at the same time in focus, it will be observed that this line consists of one long followed by two shorts (or two shorts followed by one long), the indentations bearing a general resemblance to each other and to seeds. This is long A, or "Ah." A glance at short ă



[Note.—In the wood-cut, the forms made by the excursions of the stylus for the short letters are wider than they should be.]

(as in "bat"), will show the same thing, but the seed-shaped hollows are narrower, and there are no abrupt terminations of the hollows by intervening parts of the foil which have not been touched by the needle-point.

Ē (or ay), on the screen, looked like the magnets of two Bell telephones, with the small ends turned towards each other. In the diagram they look like two Indian clubs with the handles together. The same general resemblance is observed in E short, except that, as in ă short, the volume of sound being less, the intensity was less, or (what is the measure of intensity) the path of the needle-point was

shorter, and it seldom entirely cleared the foil; the consequence being a continuous groove of irregular, but normally irregular, width.

Dr. Nolan, in faithfully transcribing the general appearance, to the eye, of these curves, was, of course, not able, in the limited time given him, to preserve the absolute thicknesses and lengths. These will be added in the memoir in the Proceedings of A. P. S., in the form of micrometric measurements to the ·001 mm.

Ī and Ĭ are much alike in general form, as also are Ō and Ŏ, the coupling of the pairs of the latter being the most striking feature. Ū and Ŭ, in the drawing, best show the difference in shape produced by less intensities; the short being drawn out, and more acicular.

OI is very interesting. The diphthong consists of ŎĪ, and the very moulds which characterize their sounds are to be observed in the cut.

OW presents a composite character, but its derivation has not yet been made out.

The above presentation of the subject is necessarily crude and imperfect, but will illustrate the possibilities of an exhaustive investigation. It should be added, that Prof. Alfred Mayer has published, in the last number of the *Popular Science Monthly*, a representation of the curves made by the ä in bat, and a comparison of them, and of a section through their middle, with the curves of the König flames, when agitated by the same sound. This was not brought to my notice till after the above work had been completed. There is a general resemblance between the forms of the excavations thus independently produced, though Prof. Mayer has one dot which I have not observed.

Telephonic Transformations.—M. A. Demoget, of Nantes, estimates that only about $\frac{1}{1800}$ of the sound which is communicated to the telephone is transmitted to the receiver. He considers that the muscular effort of the speaker is transformed: 1, into vibrations of the air; 2, into metallic vibrations; 3, into magnetic waves; 4, into electric induction; 5, into magnetic induction; 6, into metallic vibrations; 7, into vibrations of the air; 8, into vibrations of the auditory apparatus. If we suppose the loss of useful effect at each transformation to be equal, the loss would be comprised between $\frac{2}{3}$ and $\frac{1}{2}$. This represents, very nearly, the experimental efficiency of pumps.—*Les Mondes.* C.

Action of Oxygen upon Anatomic Elements.—Bert has been studying the toxic action of oxygen under high tension. He finds, by the indirect method of air confined under pressure, that the injurious influence of oxygen upon air-breathing vertebrates begins when its tension corresponds to a pressure of five or six atmospheres. The analysis of the gases contained in arterial blood shows that under this tension the coloring matter of the globules is completely saturated with oxygen, and that gas begins to be dissolved in the sanguine plasma. If the compression is long continued, the solution of oxygen becomes diffused through the tissues, and the organic oxidations are diminished, leading to an immediate reduction of the temperature of the body.—*Comptes Rendus.* C.

Pasteur Prize.—Dumas has announced the foundation of a special prize by an anonymous contributor, in the following terms: "The works of M. Pasteur have opened new processes to medicine. A prize of 6000 francs will be decreed, in 1880, by the Academy of Sciences, to the person who shall have made the most useful application of these works to the healing art."—*Comptes Rendus.* C.

Microscopic Mineralogy.—A. Michel Lévy has contributed to the *Annales des Mines* a valuable paper upon the use of the polarizing microscope, for the determination of mineral species by small sections. The investigations of Rosenbusch, Fouqué, and Descloiseux, although all embraced within the last decade, have already become classical. Lévy tabulates their conclusions, and gives a complete mathematical analysis of the angles of extinction presented by the sections of a zone, together with a practical application to the study of the principal monoclinic minerals, and of some triclinic feldspars. C.

High Furnaces.—M. L. Greever divides smelting furnaces into two classes, which he calls *trapu* (squat), and *elancé* (long). In the trapu, the height does not exceed three times the length; in the elancé, the ratio is four or more; and he admits an intermediate class, the *ordinaire*, in which the ratio is between three and four, and generally about 3·5. He compares the productions of various furnaces in England, Styria, Corinthia, America, Sweden, Germany, and France, drawing conclusions unfavorable to the elancés, which have increased so largely within the last quarter of a century.—*Annales des Mines.* C.

Influence of Electricity on Evaporation.—Mascart arranged a series of small evaporating basins under conductors, which were kept in a constant electric state by a Holtz machine, moved by water-power, and placed under a glass cage, in which the air was dried by vessels containing sulphuric acid. He found that the evaporation was constantly increased under the electrized gratings, whether the electricity was positive or negative, evaporation being sometimes doubled."—*Comptes Rendus.* C.

Cementation of Nickel.—Boussingault has experimented to find whether the carburation of nickel would affect it like iron, and, if so, whether its combination with steel would render it less oxidizable. Although he was able to carbonize the nickel as highly as steel, he did not find any increase of elasticity, hardness, or resistance to tension; he was unable to temper it; and the alloy with iron easily rusted, unless the nickel was in very large proportion. Damour found, in the meteoric iron of Santa Caterina, 34 per cent. of nickel. Boussingault exposed a piece of it under water, for more than a month, without finding the least rust. He then made a very homogeneous alloy, by melting 63 parts of steel with 37 parts of nickel, which was malleable and resisted the action of water as well as the Santa Caterina iron.—*Comptes Rendus.* C.

Proposed Prize.—The London Society of Arts offers a prize of $500, and the medal of the society, for the best memoir on the jeweler's art in the present and past times, with practical suggestions for its future development. The memoir should specify the principal works which have been produced in different countries, and the prize will not be awarded to any memoir of inferior merit. The communication should be addressed to the Secretary of the Society of Arts, John St., Adelphi, London.—*Les Mondes.* C.

Sewage of Reims.—A commission was lately appointed to advise with regard to the best disposition of the sewage water of the city of Reims. On account of immediate urgency they recommended the temporary employment of chemical clarifiers, accompanied by experiments upon the agricultural application, of such portions as were most favorably situated for the purpose. They believed that all the sewage might ultimately be applied with advantage to the soil, without requiring any previous chemical reaction.—*Ann. des Ponts et Chaussées.* C.

Delicate Manometers.—The want of manometers of great precision, capable of measuring the smallest difference of gaseous pressure, has long been felt. Peclet was the first experimenter who succeeded in approximately satisfying the want. Palamede Guzzi describes an improved instrument in *Il Politecnico* (v. 25, pp. 689–702), by which he is able to measure differences of pressure equivalent to $\frac{1}{500}$ of a millimetre of water. C.

Resistance of Iron to Repeated Blows.—Giambattista Biadego publishes a note upon the determination of the strains which iron can sustain, with special reference to Wöhler's experiments upon the effects of repeated blows. He recounts the experiments of Fairbairn (1849–61), Wöhler (1859–70), and Spangenberg; the analytical discussions of Gerber (1872), Launhardt (1873), Weyrauch (1877), and Winkler (1877); and some deductions of his own; giving a preference to the formulæ of Launhardt, as improved by Weyrauch.—*Il Politecnico.* C.

Wood Injection.—The value of creosote as a wood preserver is generally recognized, but the direct injection requires great quantities of heavy oil, and a desiccation of the injected pores. The high boiling-point of creosote (300°) does not permit its employment in vapor. John Blythe formed the idea of saturating a jet of steam with creosote in minute division, forming, so to speak, a gaseous emulsion. The apparatus comprises a high-pressure steam-boiler; another boiler containing creosote, in which the steam is saturated; a vat, filled with creosote, to be pumped into the boiler; sheet-iron cylinders, for the pieces which are to be injected; and a system of tubing connecting the several parts. In this way Mr. Blythe completely fills the heart of oak, pine, or red beech; he uses 2 to 3 kilos. of creosote for a cross-tie, and 2 kilos. of brown phenic acid per cubic metre of saturated wood or cross-ties. The cost of preparing a cross-tie, measuring 0·085 m., is from 0·60 f. to 0·70 f. The apparatus can prepare 500 ties per day; the wood comes out softened, so that it can readily be bent or shaped, but it rapidly hardens; at first it shrinks, but after a few weeks it becomes seasoned and resists the influences of moisture; finally, the fibres are greatly strengthened.—*Ann. des Ponts et Chaussées.* C.

Compound Locomotives.—M. Mallet has presented a communication to the French Academy, on the application of the compound system to locomotives on the railroad from Bayonne to Biarritz. The engine has two cranks, at right angles, driven by two cylinders, one on each side. They have a range of 0·45 m., the diameter of one being 0·24 m., the other 0·40 m. Under ordinary circumstances, the steam from the boiler passes first into the small cylinder, then into the large, where it acts expansively, and finally escapes into the chimney. But on starting, and whenever the engine is required to surmount an increased resistance, the steam may be admitted directly into the large cylinder, and the locomotive acts as an ordinary two-cylinder engine. The plan has been adopted in three engines, with four coupled wheels of 1·20 m. diameter; the boiler has 45 square metres of heating surface, and acts with an effective pressure of 10 kg. per square centimetre. They are employed in local traffic, on grades of 0·015. Their action is unexceptionable, their steadiness leaving nothing to desire, even at a speed of 40 km. per hour, and the management being no more difficult than in ordinary engines. The draught, notwithstanding the reduction of the steam-jets to one-half, is ample, so that the boiler, in spite of its small dimensions, supplies the wants of the engine abundantly. As for the consumption of fuel, the gross cost per kilometre is 4 kg. of Cardiff coal for trains weighing 50, 60 or even 70 tons. The foregoing facts are derived from a service of 40,000 km., performed since the system was adopted. They have, therefore, an important practical value.—*Ann. des Ponts et Chaussées.* C.

New Determination of the Mechanical Equivalent of Heat.—At the meeting of the Royal Society, held Jan. 24th, 1878, J. P. Joule, F. R. S., etc., read a paper, in which he gives an account of the experiments he has recently made, with a view to increase the accuracy of the results given in his former paper, published in the *Philosophical Transactions* for 1850. The result he has now arrived at, from the thermal effects of the friction of water, is, that taking the unit of heat as that which can raise a pound of water, weighed in vacuo from 60° to 61° of the mercurial thermometer; its mechanical equivalent reduced to the sea level, at the latitude of Greenwich, is 772·55 foot-pounds.—*Proceedings of the Royal Society.* *

The Byrne Cautery Battery.—At the meeting of the Institute in March, Dr. F. Cleland presented and described this battery, which is intended to provide the medical profession with a portable battery, capable of producing a considerable amount of heat, as is required in cauterizing operations. Its peculiarity is in the construction of the negative plate, which consists of a sheet of platinum, to the back of which is soldered a plate of copper, which in turn is covered with a sheet of lead. The copper extends above the platinum, and is firmly attached to the yoke. The lead covering is merely to protect the copper plate from the action of the exciting liquid.

Two of these compound plates are arranged to face the zinc plate in each cell, and four cells are placed in a case $8\frac{1}{2} \times 7\frac{1}{4} \times 4\frac{1}{8}$ inches, exposing in all less than 80 square inches each of platinum and zinc surfaces to the action of the exciting liquid, and giving, it is claimed, an electro-motive force of 7·96 volts, with an internal resistance of less than ·06 of an ohm.

Small tubes extend down into the liquid, through which air is forced by a small india-rubber ball pump, held in the hand, and by agitating the liquid greatly increases the intensity of the current, and thus enabling the operator to control the heating effect without the aid of an assistant.

This battery will raise to a white heat 20 inches of No. 16 platinum wire, and will maintain it for 30 to 40 minutes. *

Book Notices.

Matter and Motion.—By J. Clerk Maxwell. Van Nostrand's Science Series, No. 36. Price, 50 cents.

The name of the author is a sufficient guarantee for the excellence of any work which he undertakes. Some apprehension might naturally be felt that a writer who is so familiar with profound mathematical analysis, would find it difficult to treat elementary physics with such simplicity as is desirable. A brief perusal of pages 14 to 21 will show how groundless such an apprehension is, in the present instance. The fundamental principles of quaternions, including the addition and subtraction of vectors, are interpreted in a way which is perfectly lucid in itself, and which gives, even to minds of ordinary mathematical ability, satisfactory notions of some of the advantages of modern mathematical methods. The discussions on the ideas of space and time, on the error which "runs through every part of Descartes' great work, and . . . forms one of the ultimate foundations of

the system of Spinoza," and on the comparative practical importance of absolute and relative knowledge, and the "statement of the general maxim of physical science" [pp. 23-32], are fine illustrations of the advantage of combining accurate mathematical study with abstruse metaphysical speculation. The subjects of motion, force, centre of mass, work and energy, pendulum, and universal gravitation, are all well treated, the two closing chapters being especially admirable.

Some exception may very properly be taken to the definition of centrifugal force on page 171: "This is the force which must act on the body, m, in order to keep it in the circle of radius, v, in which it is moving with velocity, V. The direction of this force is towards the centre of the circle."

The following statement also seems to require some qualification: "But it is extremely doubtful whether the medium of light and electricity is a gravitating substance, though it is certainly material and has mass." Maxwell's connection of electrostatic and electromagnetic force by means of the velocity of light, and the more recent identification of the same velocity with limiting velocities in solar centripetal and centrifugal force, and in various forms of chemical activity, render it extremely probable, although by no means certain, that the luminiferous ether is material; but the instantaneous action, which is required by gravity and telephony, is wholly irreconcilable with any theory of mere material action.

We regret to notice some typographical errors, which indicate either ignorance or inexcusable carelessness in the proof-reading: *E. g.*, A_1B_2, for A_1B_1, p. 35; *oo* for *ao*, p. 35; instance, for instants, p. 40; 980′, for 980, p. 42; O, for 0, p. 115; meter, for metre, *passim*.

C.

REPORTS AND AWARDS OF THE INTERNATIONAL EXHIBITION, 1876.—Edited by Francis A. Walker, Chief of the Bureau of Awards. J. B. Lippincott & Co., 1877. Group II, Pottery, Porcelain, Brick Clays, Cements and their Materials, etc.

The general report of the Judges of this group covers 250 pages, exclusive of the report on awards. It commences with a short historical sketch of the progress of the potter's art within the last one hundred years, and then gives a general review of the display of pottery and porcelain at the Centennial as a whole.

The number of exhibits in the group, including glassware, is 592, of which 199 are from the United States; some of the exhibits from foreign countries are remarkable for the number of pieces, and the size and value of individual specimens.

Europe was not represented at her best, many of the leading English and Continental houses being represented indifferently, or not at all.

Oriental porcelain was represented by collections of great interest, extent and variety; the Japanese constituting the most important contribution to the Ceramic Department.

The contribution of American pottery is noticed somewhat more in detail, because of its importance to the country as a manufacturing industry, and also because of its sudden and remarkable development within a comparatively few years. The history of this growth forms a preface to the detailed report on the American exhibits.

Of these detailed reports there is one for each nationality, all of which are written with evident impartiality and good judgment.

Among the special reports, that by Prof. Henry Wurtz, on the chemistry and composition of the porcelains and porcelain rock of Japan, is of especial value.

The report on cements and artificial stone, or bricks, brick machinery, and pavements, etc., by Gen. Q. A. Gilmore, covers the ground remarkably well, and, from the high reputation of the writer, will be received as authority on these subjects.

The experiments on the tensile and crushing strength of cements, the results of which are given on page 167, are worthy of notice.

The reports on awards, commencing with page 251, are uninteresting, covering, as they do, only the reasons for which medals are recommended.

Reports on quite a number of other groups have been received and will be noticed hereafter.

Meanwhile we would call attention to what seems to be an error in design and arrangement. The report on each group is contained in a separate pamphlet, with independent paging, evidently not intended to be bound into volumes; there are no indexes to the separate pamphlets, and this independent paging makes it impossible to prepare one for the whole set, and therefore their value for purposes of reference is greatly reduced.

The mechanical execution is good, being printed on excellent tinted paper, in large, clear type.

PROCEEDINGS OF SOCIETIES.

Engineers' Club of Philadelphia.—At the meeting held March 16th, Mr. Rudolph Herring read a paper on "Bearing Piles," in which he discusses the formulæ for the sustaining power, size and disposition in any foundation, given by different authors. The uncertainty as to the proper formulæ for pile driving, has led most authors, and all careful practical engineers, to give a wide margin of safety in loading them.

It is well known that the formulæ generally given in books vary greatly among themselves, because based on experiments in which the conditions are not the same, and Mr. Herring has done a good work in assembling all the authorities on the subject, and, by a proper comparison and analysis of the formulæ, showing a reasonable degree of coincidence in many of them, and enabling engineers to make such a selection as will lead to satisfactory results in each special case. He concludes that the only method which can be relied upon, is one that introduces as one factor the actual distance which a pile sinks under the last blow of a ram of a known weight and fall.

Mr. W. A. Ingham called attention to the drawings of Mr. Loftis Perkins' "steam boiler and engine for high pressure," calculated to work under pressure from 350 to 500 pounds to the square inch.

Mr. H. C. Lewis gave an interesting account of the erection of the temporary bridge over the Raritan River, at New Brunswick. The bridge is feet long, and was erected in less than four days from the time the old one was burned.

Mr. Chas. E. Billin exhibited a new form of tripod for surveying instruments, embodying a combination of the ball and socket motion and four leveling screws, by which it is claimed that two-thirds of the time in field operation is saved.

Mr. D. McN. Stauffer made some further remarks on the fall of the South Street Bridge, based on the borings made by the chief engineer, to which reference was made in our last issue.

Prof. L. M. Haupt read a paper on "the Removal of Smith's Island." The great development of the commercial interest of Philadelphia has led to a greatly increased demand for wharfage room and deeper water. To accomplish this it is proposed to extend the wharves and further contract the channel opposite Smith s Island, now only about 800 feet in width.

Prof. Haupt, however, concludes that to widen the channel along the island to 1000 feet, to a depth of 18 feet, would require the removal of 5,000,000 cubic yards of material, at a cost of about $1,000,000. That the same depth and width of channel may be obtained, if desired, for less than one-tenth the cost of dredging, by a careful adjustment of the regimen of the river by jetties or bottom dams, etc. He showed, by a comparison of the maps and records, that from 1762 to 1868, 106 years, the movement of the lower end of Smith's Island, up stream, has been 1900 feet.

Franklin Institute.

Hall of the Institute, April 17th, 1878.

The stated meeting was called to order at 8 o'clock P. M., the Vice-President, J. E. Mitchell, in the chair.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 10 persons were elected members of the Institute; and the following donations to the Library were reported:

Quarterly Report of the Chief of the Bureau of Statistics. Treas. Department. Ending September 30th, 1877.
From the Chief of Bureau.

National Academy of Sciences. Constitution and Membership, 1876; Proceedings, Vol. 1; Biographical Memoirs, Vol. 1.
From J. E. Hilgard, Secretary.

Sermons preached chiefly in the College chapel, by Jas. Walker, D. D. Boston, 1877. From American Unitarian Assoc., Boston.

Second Geological Survey of Pennsylvania. 1876.
H. H. H. Report of Progress in the Cambria and Somerset district of the Bituminous coal fields of Pennsylvania. By F. & W. G. Platt. Part 2.
I. I. Oil Well records and Levels. By J. F. Carll.
K. K. Report of Progress in the Fayette and Westmoreland district. By J. J. Stevenson. Harrisburg, 1877.
From Sec. of Board of Commissioners of Second Geol. Survey, Pa.

Report of the Geological Exploration of the 40th Parallel. By C. King. Vol. 4. Ornithology and Palæontology.
From the Chief of Engineers.

Specifications and Drawings of Patents issued from the U. S. Patent Office. October, 1877. From the Patent Office.

Verzeichniss der Mitglieder des Vereins Deutscher Ingenieur. 1878. From the Society.

Second Annual Report of the State Survey of New York, for 1877. From James F. Gardner, Director.

Fifth Annual Report of the Lowell Water Board, to City Council. January 1st, 1878. From G. E. Evans, Chief Engineer.

Delaware River, from Fisher's Point to Kaighn's Point. Surveyed in 1843. From L. M. Haupt, C.E.

English Patent Specifications. No. 4801, Dec. 12th, to No. 5069, Dec. 30th, 1876. And No. 1, Jan. 1st, to No. 2000, May 15th, 1877.

Abridgments relating to Fire Engines, etc., 1625–1866. Chains, Chain Cables, etc., 1634–1866.

Washing and Wringing Machines, 1691–1866.

Disclaimer and Memorandum of Alteration No. 3344, 1876.

Commissioners of Patents' Journal. Nos. 2461 and 2462, 1877.

Subject Matter Index for 1876.

From the Commissioners of Patents, London, Eng.

The Secretary reported that the Committee on Science and the Arts, at the meeting held on the 1st inst., recommended the award of the Scott Legacy Premium and Medal to Messrs. Heyl & Brehmer, for their Book Sewing Machine.

The Secretary presented and read a synopsis of the report of the committee on Dynamo-Electric Machines.[i]

Prof. Persifor Frazer presented a study of the Phonograph Record,[ii] illustrated by projecting on the screen portions of the tin-foil, showing the form of the indentations produced by different sounds.

Mr. D. S. Holman called attention to his new arrangement of the projecting microscope, for producing on the screen pictures of small opaque objects. This was used in the illustrations given by Prof. Frazer, and it is believed for the first time for this purpose.

The Secretary's report embraced Hand's Differential Pressure Valve; Baldwin's Flower Vase; Bingham's Counting Frame, and other pantographic lessons.

The amendment to Article XIV of the By-Laws, proposed at the stated meeting in February, was adopted.[iii]

On motion, the meeting adjourned.

J. B. KNIGHT, *Secretary.*

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i See page 289.

ii See page 348.

iii See page 215, this Vol.

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OF THE

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OF THE STATE OF PENNSYLVANIA,

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Vol. CV.	JUNE, 1878.	No. 6.

REPORT OF THE COMMITTEE ON DYNAMO-ELECTRIC MACHINES.

[Continued from Vol. lxxv, page 303.]

THE INVESTIGATIONS OF THE SUB-COMMITTEE ON ELECTRICAL MEASUREMENTS.

By Profs. Edwin J. Houston and Elihu Thomson.

Now that the conversion of motive power into electricity, and the use of the latter for lighting, the deposition of metals, etc., are rapidly gaining in importance, it has become desirable that reliable data be obtained as to the efficiency of the various types of machines designed for producing electrical current from motive power.

In entering this comparatively new field of research, we have been met by peculiar difficulties, owing to conditions, that do not exist in the various forms of batteries used as sources of electrical power.

In many battery circuits a high external resistance may be employed, and the electromotive force remain comparatively constant, while in dynamo-electric machines, in which the reaction principle is employed, the introduction of a very high external resistance into the circuit must be necessarily attended by decided variations in the

electromotive force, due to changes in the intensity of the magnetic field in which the currents have their origin. Moreover, a considerable difficulty is experienced in the great variations in the behavior of these machines when the resistance of the arc, or that of the external work, is changed. Changes, due to loss of conductivity by heating, also take place in the machine itself.

The variations above mentioned are also attended by changes in the power required to drive the machine, and in the speed of running, which again react on the current generated.

There are certain normal conditions in the running of dynamo-electric machines designed for light, under which all measurements must be made, viz.:

1. The circuit must be closed, since, on opening, all electrical manifestations cease.

2. The circuit must be closed through an external resistance equal to that of the arc of the machine.

3. The arc taken as the standard must be the normal arc of the machine. This condition can only be fulfilled by noticing the behavior of the machine while running, as to the absence of sparks at the commutator, the heating of the machine, the regularity of action in the consumption of carbons in the lamp, etc.

4. The speed of the machine must be, as nearly as possible, constant.

5. The power required to maintain a given rate of speed must be, as nearly as possible, constant.

The machines submitted to us for determinations, were as follows, viz.:

1. Two machines of different size, and of somewhat different detailed construction, built according to the invention of Mr. C. F. Brush, and styled respectively in our report as A^1, the larger of the two machines, and A^2 the smaller.

2. Two machines known as the Wallace-Farmer machines, differing in size, and in minor details of construction, and designated respectively as B^1, the larger of the two, and B^2, the smaller. In the case of the machine B^1, the experiments were discontinued after the measurement of the resistances were made, insufficient power being at our disposal to maintain the machine at its proper rate of speed.

3. A Gramme machine of the ordinary construction.

All the above machines are constructed so that the whole current

traverses the coils of the field magnets, being single current machines, in which the reaction principle is employed. In the case of the machine designated A^2, the commutators are so arranged as to permit the use of two separate circuits when desired.

For the purpose of preserving a ready measure of the current produced by each machine, under normal conditions, a shunt was constructed by which an inconsiderable but definite proportion of the current was caused to traverse the coils of a galvanometer, thus giving with each machine, a convenient deflection which could at any time be reproduced. As the interposition of this shunt in the circuit did not appreciably increase its resistance, the normal conditions of running were preserved.

As indicating the preservation of normal conditions in any case, the speed of running and the resistances being the same as in any previous run, it was found that when there was an equal expenditure of power, as indicated by the dynamometer, the current produced, as indicated by the galvanometer, was in each case the same.

Certain of the machines experimented with heated considerably on a prolonged run; most of the tests, therefore, were made when the machines were as nearly as possible at about the temperature of the surrounding air. It is evident that no other standard could be well adopted, as under a prolonged run the temperature of the different parts of the machine would increase very unequally; and, moreover, it would be impossible to make any reliable measurements of the temperatures of many such parts.

In measuring the resistance of the machines, a Wheatstone's bridge, with a sliding contact, was used in connection with a delicate galvanometer and a suitable voltaic battery. In taking the resistances of the machines, several measurements were made with the armatures in different positions, and the mean of these measurements taken as the true resistance.

It was, of course, a matter of the greatest importance to obtain a value for the resistance of the arc in any case, since upon the relative values of this resistance, and that of the machine, the efficiency would in any given case, to a great extent, depend. In each case, the arc of which the resistance was to be taken, was that which was obtained when each machine was giving its average results as to steadiness of light and constancy of the galvanometer deflection.

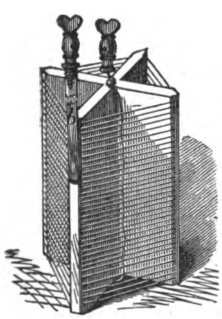
The method adopted for the measurement of the arc was that of substitution, in which a resistance of German silver wire immersed

in water, was substituted for the arc, without altering any of the conditions of running. This substituted resistance was afterwards measured in the usual way, and gave, of course, the resistance of the arc. It could, therefore, when so desired, serve as a substitute for the arc. No other method of obtaining the arc resistance appeared applicable, since the constancy of the resistance of the arc required the passage of the entire current through the carbons.

It may be mentioned, as an interesting fact in this connection, that when the current flowing was great, the arc corresponding thereto had a much lower resistance than when the current was small. This fact is, of course, due to increased vaporization, consequent on increased temperature in the arc.

In determining the true arc resistance, the resistance of the electric lamp controlling the arc was measured separately, and deducted from the result obtained with the German silver wire substitute.

For ease of obtaining a resistance of German silver wire equal in any case to that of the arc, a simple rheostat was constructed, by winding, upon an open frame, such a length of wire as was judged to be in excess of the resistances of any of the arcs to be measured. By means of a sliding contact, successive lengths of the wire were added until the conditions as above stated were reproduced. The figure shows the arrangement of the rheostat. With this arrangement, no difficulty was experienced in reproducing the same conditions of normal running, as when the arc was used. The same conducting wires were used throughout these experiments. Being of heavy copper, their resistance was low, viz.: about ·016 ohm.



Having thus obtained the circuit resistances, we proceeded to determine the value of the current. Here the choice of a number of methods presented itself. We selected two methods, one based on the production of heat in a circuit of known resistance, and the other upon the comparison of a definite proportion of the current with that of a Daniell's battery.

In the application of the first method, eight litres of water, at a known temperature, were taken, and placed in a suitable non-conducting vessel. In this was immersed the German silver wire before mentioned, and the sliding contact so adjusted as to afford a resistance equal to that of the normal arc of the machine under con-

sideration. This was now introduced into the circuit of the machine. All these arrangements having been made, the temperature of the water was accurately obtained, by a delicate thermometer, reading readily to quarter degrees Fahrenheit. The current from the machine running under normal conditions was allowed to pass, for a definite time, through the calorimeter so provided. From the data thus obtained, after making the necessary corrections as to the weight of the water employed, the total heating effect in the arc and lamp, as given in Table II, was deduced.

Since the heat in various portions of an electrical circuit is directly proportional to the resistance of those portions, the total heat of the circuit was easily calculated, and is given in Table III, in English heat units. For ease of reference, the constant has been given for conversion of these units into the now commonly accepted units of heat.

Having thus obtained the heating effect, the electrical current is readily determined by the well known formula,

$$C = \sqrt{\frac{W h \times 772}{R t c}},$$

where $C =$ the veber current per ohm, W the weight of water in pounds, h the increase of temperature in degrees Fahr., 772 Joule's constant, R the resistance in ohms, t the time in seconds, and c the constant, ·737335, the equivalent in foot-pounds of one veber per per ohm per second. The currents so deduced for the different machines are given in Table IV.

The other method employed for obtaining the current, viz., the comparison of a definite portion thereof, with the current from a Daniell's battery, was as follows: a shunt was constructed, of which one division of the circuit was ·12 ohm, and the other 3000 ohms. In this latter division of the circuit was placed a low-resistance galvanometer, on which convenient deflections were obtained. This shunt being placed in the circuit of the machine, the galvanometer deflections were carefully noted. To the resistance afforded by the shunt, such additional resistance was added, as to make the whole equal to that of the normal arc of the machine. These substituted resistances were immersed in water, in order to maintain an equable temperature.

Three Daniell's cells were carefully set up and put in circuit with the same galvanometer used above, and with a set of standard resistance

coils. Resistances were unplugged sufficient to produce the same deflections as those noted with the shunt above mentioned. The shunt ratio, as nearly as could conveniently be obtained, was $\frac{1}{25000}$. Then the formula,

$$C = \frac{s\,n \times 1{\cdot}079}{R},$$

where C equals the veber current, s the reciprocal of the shunt ratio, n the number of cells employed, 1·079 the assumed normal value of the electromotive force of a Daniell's cell, and R the resistances in the circuit with the battery, gives at once the current. In comparison with the total resistances of the circuit, the internal resistance of the battery was so small as to be neglected.

The results obtained were as follows:

Name of Machine.	Shunt ratio.	Number of Daniell's cells.	Resistances unplugged.	Speed of Machine.
Large Brush, . .	$\frac{1}{25000}$	3	2710 ohms.	1340 rev.
Small Brush, . .	"	"	3700 "	1400 "
Wallace-Farmer, { .	"	"	8320 "	844 "
Wallace-Farmer, { .	"	"	6980 "	1040 "
Gramme, ...	"	"	4800 "	800 "

The veber currents, as calculated from the above data, are given in Table IV.

From the results thus derived, the electromotive force was deduced by the general formula,

$$E = C \times R.$$

The electromotive force thus calculated will be found in Table IV.

Statements are frequently made, when speaking of certain dynamo-electric machines, that they are equal to a given number of Daniell's, or other well-known, battery cells. It is evident, however, that no such comparison can properly be made, since the electromotive force of a dynamo-electric machine, in which the reaction principle is employed, changes considerably with any change in the relative resistances of the circuit of which it forms a part, while that of any good form of battery, disregarding polarization, remains approximately constant. The internal resistance of dynamo-electric machines is, as a rule, very much lower than that of any ordinary series of battery

cells, as generally constructed, and, therefore, to obtain with a battery, conditions equivalent to those in a dynamo-electric machine, a sufficient number of cells in series would have to be employed to give the same electromotive force; while, at the same time, the size of the cells, or their number in multiple arc, would require to be such that the internal resistance should equal that of the machine.

Suppose, for example, that it be desired to replace the large Brush machine by a battery whose electromotive force and internal and external resistances are all equal to that of the machine, and that we adopt as a standard a Daniell's cell, of an internal resistance of, say, one ohm. Referring to Table IV, the electromotive force of this machine is about 39 volts, to produce which about 37 cells, in series, would be required; but, by Table II, the internal resistance of this machine is about ·49 ohm. To reduce the resistance of our standard cell to this figure, when 37 cells are employed in series, 76 cells, in multiple arc, would be required. Therefore, the total number of cells necessary to replace this machine would equal 37×76, or 2812 cells, working over the same external resistance. It must be borne in mind, however, that although the machine above-mentioned is equal to 2812 of the cells taken, that no other arrangement of these cells than that mentioned, viz., 76 in multiple arc, and 37 in series, could reproduce the same conditions, and, moreover, the external resistances must be the same. The same principles, applied to the other machines, would, when the internal resistance was great, require a large number of cells, but arranged in such a way as to be extremely wasteful, from by far the greater portion of the work being done in overcoming the resistance of the battery itself.

The true comparative measure of the efficiency of dynamo-electric machines as means for converting motive power into work derived from electrical currents, whether as light, heat, or chemical decomposition, is found by comparing the units of work consumed with the equivalent units of work appearing in the circuit external to the machine. In Table V, the comparative data are given. In the first column the dynamometer reading gives the total power consumed; from which are to be deducted the figures given in the second column, being the work expended in friction, and in overcoming the resistance of the air; although, of course, it must be borne in mind, that, that machine is the most economical in which, other things being equal, the resistance of the air and the friction, are the least. The third

column gives the total power expended in producing electrical effects, a portion only of which, however, appears in the effective circuit, the remainder being variously consumed in the production of local circuits in the different masses of metal composing the machines. This work eventually appears as heat, in the machine. Columns four, five and six give respectively the relative amounts of power variously appearing as heat in the arc, in the entire circuit, and as heat due to local circuits in the conducting masses of metal in the machine, irrespective of the wire. This latter consumption of force may be conveniently described as due to the *local action* of the machine, and is manifestly comparable to the well known local action of the voltaic battery, since in each case it not only acts to diminish the effective current produced, but also adds to the cost.

We desire to call attention to the fact, that in all the determinations conducted by us, we have been particularly careful to ensure a definite relation between the external and internal resistances in each case, a condition of paramount importance in the effective working of these machines. It is evident indeed, that no determinations made with an unknown or abnormal external resistance can be of any value, since the proportion of work done, in the several portions of an electrical circuit, depends upon, and varies with, the resistances they offer to its passage. If, therefore, in separate determinations with any particular machine, the resistance of that part of a circuit of which the work is measured be, in one instance large, in proportion to that of the remainder of the circuit, and in another small, the two measurements thus made would give widely different results, since in the case where a large resistance was interposed in this part of the circuit, the percentage of the total work appearing there would be greater than if the small resistance had been used.

When an attempt has been made to determine the efficiency of a single machine, or of the relative efficiency of a number of machines, by noting the quantity of gas evolved in a voltameter, or by the electrolysis of copper sulphate in a decomposing cell, when the resistance of the voltameter or decomposing cell did not represent the normal working resistance, it is manifest that the results cannot properly be taken as a measure of the actual efficiency.

In Table II it will be found that, in general, where the machine used had a high internal resistance, the arc resistance normal to it was also high, but they are not necessarily dependent upon each other.

TABLE II.—Resistances of Dynamo-Electric Machines.

From Determinations by Edwin J. Houston and Elihu Thomson.

Name of Machine.	Temperature in degrees F.	Resistances: Of Machine +conductor.	Resistances: Of Arc +Lamp.	Resistance of conducting Wire.	Resistance of Lamp, exclusive of Arc.	Corrected Resistances: Of Machine —conductor.	Corrected Resistances: Of Arc —Lamp.	Total resistance of the Circuit. Ohms.	Remarks.
A^1, Large Brush, .	73½	·485	·57	·016	·032	·483	·54	1·055	At beginning of run.
A^1, " " .	88	·495	·82	·016	·032	·493	·79	1·315	After running 25 min.
A^2, Small Brush, .	74	1·255	1·70	·016	·032	1·239	1·67	2·955	Arranged for low resist.
A^2, " " .	74	5·06		·016		5·044			" " high "
B^1, Large Wallace,	74	4·60	1·98	·016	·032	4·584	1·95	6·58	Machine cold.
B^1, " "	118	5·13							After 40 min. run.
B^2, Small Wallace,	74	4·96	2·87	·016	·1025	4·944	2·77	7·83	At 844 rev.
B^2, " "	74	4·96	3·24	·016	·1025	4·944	3·18	8·24	" 1000 rev.
Gramme, ...	68	1·685	1·35	·016	·1025	1·669	1·25	3·04	Arc not normal.
"	68	1·685	1·97	·016	·1025	1·669	1·87	3·66	Arc normal.

The arc resistance depends on the intensity of the current, the nature of the carbons, and on their distance apart. Other conditions being the same, the resistance of the arc is less when the current is great.

Since all the machines examined were built for lighting, it will readily be seen that, other things being equal, that machine is the most economical in which the work done in the arc bears a considerable proportion to that done in the whole circuit, and since, with any given current, the work is proportional to the resistance, we have in Table II the data for comparison in this regard. For example, in the second determination of A^1, the large Brush machine, the resistance of the arc constitutes considerably more than one-half the total resistance of the entire circuit, while in B^2, the small Wallace-Farmer machine, it constitutes somewhat more than one-third the total resistance. These relative resistances give, of course, only the proportion of the current generated, which is utilized in the arc as light and heat, the conditions of power consumed to produce the current not being there expressed.

During any continued run, the heating of the wire of the machine, either directly by the current, or indirectly from conduction from those parts of the machine heated by local action, as explained in a former part of this report, produces an increased resistance, and a consequent falling off in the effective current. Thus, in Table II, at the temperature of 73·5° Fahr., A^1, the large Brush machine, had a resistance of ·485 ohm, while at 88° Fahr., at the armature coils, it was ·495 ohm. These differences were still more marked in the case of B^1.

In A^2, the small Brush machine, it will be noticed that two separate values are given for the resistance of the machine. These correspond to different connections, viz., the resistance, 1·239 ohms, being the connection at the commutator for low resistance, the double conducting wires being coupled in multiple arc, while 5·044 ohms represent the resistance when the sections of the double conductor are coupled at the commutator in series.

Referring to Table III, the numbers given in the column headed "Heat in Arc and Lamp," are the measure of the total heating power in that portion of the circuit external to the machine. They do not, however, in the case of any machine, represent the energy which is available for the production of light, which depends also on the nature and the amount of the resistance over which it is expended.

TABLE III.—Thermic Effects of Dynamo-Electric Machines.

From Determinations by Edwin J. Houston and Elihu Thomson.

NAME OF MACHINE.	Galvanometer deflection with shunt.	Heating Effect in Arc and Lamp.			Resistance of Calorimeter equal to arc.	Heat in arc and lamp, in pounds H_2O, 1° F.	Total heat of the circuit, in lbs. H_2O, 1° F.	Heat per ohm, per second.	Speed of machine rev. per min.	Dynamometer reading, including friction.
		Lbs. H_2O.	Increase degrees Fahr.	Duration of run.						
A^1, Large Brush, . .	51½°	18·64	23·25	10	·82	43·338	69·49	·881	1340	107606
A^2, Small Brush, . .	34	18·63	9·09	5	1·70	33·87	58·87	·332	1200	117700
A^2, " " . .	37	18·63	18·66	8	1·70	43·45	75·57	·426	1400	124248
B^2, Small Wallace, . .	25½	18·63	11·50	12	2·87	17·85	48·70	·104	844	97068
B^2, " " . .	25½	18·63	4·92	6	2·87	15·28	41·69	·089	844	97068
B^2, " " . .	24½	18·64	10·75	10	3·28	20·04	50·34	·102	1040	128544
Gramme, ...	38	18·64	16·25	10	1·97	30·29	56·28	·256	800	60992

For conversion to new heat units — 1 lb. water, 1° F., = 259·185 grammes of water, 1° C.

For example, the heat in arc and lamp are practically the same in each of the Brush machines, if the measurement of the smaller of these machines be taken at the higher speed. The amount of light produced, however, is not the same in these two instances, being considerably greater in the case of the larger machine. The explanation of this apparent anomaly is undoubtedly to be found in the different resistances of the arcs in the two cases. In the large Brush machine the carbons are nearer together than when the small machine is used. This suggests the very plausible explanation, that the cause of the difference is to be attributed to the fact, that, although the total heating effect is equal in each case, when the large machine is used, the heat produced is evolved in a smaller space, and its temperature, and consequent light-giving power, thereby largely increased.

It would seem, indeed, that any future improvements made in the direction of obtaining an increased intensity of light from a given current, will be by concentrating the resistance normal to the arc in the most limited space practicable, thereby increasing the intensity of the heat, and, consequently, its attendant light.

It may be noted, in this connection, that in all the cases in which the resistance of the arc was low, the photometric intensity was high. This, indeed, might naturally be expected, since a great intensity of heat would, under existing conditions of the use of the arc, admit of increased vaporization, and consequent lowering of the resistance.

In the column headed "Total Heat of Circuit," are given the quantities of heat developed in the whole circuit, which numbers, compared with those in the preceding column, furnish us with the relative proportions of the work of the circuit, which appear in the arc and lamp.

The column headed "Heat per ohm per second," gives the relative work per ohm of resistance in each case, and these numbers, multiplied by the total resistance, give the total energy of the current expressed in heat units per second.

In Table IV are given the results of calculation and measurement, as to the electrical work of each machine. It is evident, to those acquainted with the principles of electrical science, that in the veber current and the electromotive force, we have the data for comparing the work of these machines with that of any other machine or battery, whether used for light, heat, electrolysis, or any other form of electrical work.

TABLE IV.—CURRENT AND ELECTROMOTIVE FORCE OF DYNAMO-ELECTRIC MACHINES.

From Determinations by EDWIN J. HOUSTON and ELIHU THOMSON.

NAME OF MACHINE.	VEBER CURRENT PER OHM PER SEC.		ELECTROMOTIVE FORCE IN VOLTS.		Per cent. of the work of current appearing in the arc.	Corresponding Dynamometric Values.	REMARKS.
	From heat developed.	By comparison with Daniell's batt.	Calc. from heat and resistance.	By comparison with Daniell's batt.			
A^1, Large Brush, . .	30·37	29·87	39·94	39·28	60·08	107606	Speed 1340 rev.
A^2, Small Brush, . .	18·63		55·05			117700	" 1200 "
A^2, " " . .	21·12	21·87	62·41	64·63	56·51	124248	" 1400 "
B^2, Small Wallace, .	10·42	9·73	81·59	76·19	35·38	97068	" 844 "
B^2, " " .	9·64		75·48				" 844 "
B^2, " " .	10·33	11·16	85·12	91·96	38·59	128544	" 1040 "
Gramme, ...	16·38	16·86	59·95	61·71	51·09	60992	" 800 "

As might be supposed, the values given in Table IV, of the veber current, approximate relatively to the photometric values, as will be seen from an examination of that part of the general report of the Committee relating to photometric measurements.

The values of the veber current, as deduced from the heat developed, and from the comparison with a Daniell's cell, do not exactly agree; nor could this have been expected, when the difficulty of minutely reproducing the conditions as to speed, resistance, etc., is considered.

By comparison of the electromotive force of the different machines, it appears that no definite unit seems to have been aimed at by all the makers as that best adapted to the production of light.

Table V is designed especially to permit a legitimate comparison of the relative efficiency of the machines, as well as their actual efficiency in converting motive power into current. The actual dynamometer reading, for which we are indebted to the sub-committee on the measurement of power, is given in the first column. On account of differences of construction, and differences in speed of running, the friction and resistance of the air vary greatly, being least with the Gramme, as might be expected, since the form of the revolving armature, and the speed of the machine, conduce to this result. This is, of course, a point greatly in favor of the Gramme machine.

That portion of the power expended available for producing current is given in the third column, being the remainder, after deducting the friction, as above mentioned; but this power is not in any case fully utilized in the normal circuit. This is found to be the case by comparing calculations of the total work of the circuit in foot-pounds, as given in the appropriate column, with the amount expended in producing such current.

For instance, in the case of A^1, the large Brush machine, the available force for producing current is 89656 F. P. per minute, of which only 53646 reappear as heat in the circuit. The balance is most probably expended in what we have termed *local action*, that is, the production of local currents in the various conducting masses of metal composing the machine. The amount thus expended in local action is given in the column designated "F. P. unaccounted for in the Circuit." A comparison of the figures in this column is decidedly in favor of the Gramme machine, it requiring the smallest proportion

TABLE V.—EFFECTS OF DYNAMO-ELECTRIC MACHINES IN FOOT-POUNDS PER MINUTE.

From Determinations by EDWIN J. HOUSTON and ELIHU THOMSON.

NAME OF MACHINE.	Dynamometer reading. F. P. consumed.	Friction and resistance of air.	F. P. consumed, after deducting friction.	F. P. appearing in arc as heat.	F. P. appearing in whole circuit.	F. P. unaccounted for in the circuit.	Per cent. of power utilized in arc.	Per cent. of effect after deduct. friction.
A^1, Large Brush, .	107606	17950	89656	33457	53646	36010	31	37½
A^2, Small Brush, .	117700	12328	105372	26148	45448	59924	22	25
A^2, " " . .	124248	14976	109272	33543	58340	50932	27	31
B^2, Small Wallace, .	97068	7800	89268	13780	37596	51672	14	15½
B^2, " " .	128544	11072	117472	15469	38862	78610	12	13
Gramme, . .	60992	4512	56480	23384	43448	13032	38	41

For conversion into Gramme-metres — 1 foot-pound = 138 Gramme-metres, nearly.

of power expended, to be lost in local action. When, however, we consider that the current produced by the large Brush machine is nearly double that produced by the Gramme, the disproportion in the local action is not so great. The columns containing the percentages of "Power utilized in the Arc," and "Useful Effect after deducting Friction," need no special comment.

The determinations which we have made, as described in the foregoing part of this report, have enabled us to form the following opinions as to the comparative merits of the machines submitted to us for examination.

1. The Gramme machine is the most economical, considered as a means for converting motive power into electrical current, giving in the arc a useful result equal to 38 per cent., or to 41 per cent. after deducting friction and the resistance of the air. In this machine the loss of power in friction and local action is the least, the speed being comparatively low. If the resistance of the arc is kept normal, very little heating of the machine results, and there is an almost entire absence of sparks at the commutator.

2. The large Brush machine comes next in order of efficiency, giving in the arc a useful effect equal to 31 per cent. of the total power used, or 37½ per cent. after deducting friction. This machine is, indeed, but little inferior in this respect to the Gramme, having, however, the disadvantages of high speed, and a greater proportionate loss of power in friction, etc. This loss is nearly compensated by the advantage this machine possesses over the others of working with a high external compared with the internal, resistance, this also ensuring comparative absence of heating in the machine. This machine gave the most powerful current, and consequently the greatest light.

3. The small Brush machine stands third in efficiency, giving in the arc a useful result equal to 27 per cent., or 31 per cent. after deducting friction. Although somewhat inferior to the Gramme, it is, nevertheless, a machine admirably adapted to the production of intense currents, and has the advantage of being made to furnish currents of widely varying electromotive force. By suitably connecting the machine, as before described, the electromotive force may be increased to over 120 volts. It possesses, moreover, the advantage of division of the conductor into two circuits, a feature which, how-

ever, is also possessed by some forms of other machines. The simplicity and ease of repair of the commutator are also advantages. Again, this machine does not heat greatly.

4. The Wallace-Farmer machine does not return to the effective circuit as large a proportion of power as the other machines, although it uses, in electrical work, a large amount of power in a small space. The cause of its small economy is the expenditure of a large proportion of the power in the production of local action. By remedying this defect, a very admirable machine would be produced.

We regret that a machine of the Siemens type was not placed at our disposal, since whatever value our determinations may possess, would then have been increased by embodying data concerning a machine so widely and so favorably known, especially as the Siemens machine employs an armature differing in construction from that of any of the machines examined, wire only being revolved, a construction, which theoretically favors economy in working.

After careful consideration of all the facts embodied in the preceding reports, the Committee has unanimously concluded that the small Brush machine, though somewhat less economical than the Gramme machine, or the large Brush machine, for the general production of light and of electrical currents, is, of the various machines experimented with, the best adapted for the purposes of the Institute, chiefly for the following reasons:

1. It is admirably adapted to the production of currents of widely varying electromotive force, and produces a good light.

2. From the mechanical details of its construction, especially at the commutators, it possesses great ease of repair to the parts subject to wear.

The Committee therefore recommends that it be selected for purchase.

The Committee desires to express its thanks to Prof. H. W. Wiley, for the loan of the Gramme machine, to the Committee of the Central High School, to the Fales & Jenks Manufacturing Co., to Mr. J. W. Sutton, to Messrs. Wm. Sellers & Co., to Messrs. W. W.

Goodwin & Co., for the loan of apparatus and other favors, and to Mr. Thos. H. McCollin for his valuable services in taking the photographs from which the illustrations of the carbon points were made.

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EDWIN J. HOUSTON,
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ERRATA.—In the table on p. 302, this vol., the weight of wire in the Gramme machine should be: on armature, $9\frac{1}{2}$ lbs.; and on field-magnets, $57\frac{1}{2}$ lbs.

THE TELEPHONE.

By BROWN AYRES.

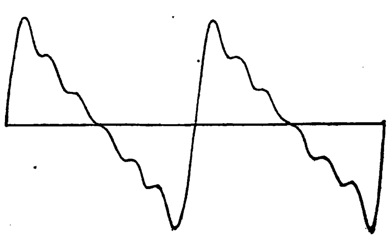
Probably no invention ever attracted more universal and interested attention than the telephone, and it is safe to say that none was ever more deserving of it, whether we regard the instrument in its intrinsic interest from a scientific standpoint, or whether we look at it in its purely practical bearing. The public, by a legion of newspaper articles and public lectures, has become moderately familiar with the general construction and operation of the instrument, but no one seems as yet to have considered it in its theoretic aspects, nor to have given to the public many very remarkable facts that can hardly have failed to have attracted the attention of any one who has worked to any considerable extent with the instrument. An outline of this theory, and a few of these facts, it is the purpose of the writer to present in the present paper, with the hope that it may at least stimulate others more fully prepared for the task to give the subject more thorough attention.

The complete understanding of the action of the telephone, covering, as it does, some of the most refined portions of Dynamics, would require mathematical processes of the greatest complexity and difficulty; but a clear understanding of the general principles of the

operation of the instrument, with enough of the quantitative relations involved to give us definite ideas in regard to its action, need not be inconsistent with a limited knowledge of the higher mathematical processes.

In attempting to form a conception of the action of the telephone, we must keep constantly before our minds the mutual relations of pitch, intensity, and quality in the sensations of sound, and their relations to the corresponding amounts of energy involved in the various transformations through which the energy of the sound wave passes between its initial and final states as kinetic energy of atmospheric vibration. We may, to give breadth to our view of the subject, regard the instrument in a generalized form. As such, we shall find that it consists of three essential parts: Firstly, the mechanism which receives the energy of the vibrating air, *e. g.*, the plate; secondly, the mechanism for transforming the energy of sound motion so received into an equivalent of electric and other energy, or for regulating the development of electric energy in an external source, and lastly, the mechanism for reconverting the electric energy into aerial undulations. I have pictured the instrument thus in its generality, because in special points the various telephones differ, and the present method of construction can hardly be expected to be rigorously adhered to.

Fig. 1.



The requirement for an articulating telephone is that the working margin of the electric current and the action of the mechanism shall be so related that the sound given forth at the distant end of the line shall be in relative pitch, intensity and quality, an accurate reproduction of the sound initially produced. In all forms of telephone yet devised, as we shall directly see, the strength of the transmitted current is in direct proportion to the kinetic energy of an air particle engaged in the production of a given sound, and is independent of the pitch; so that for the purposes of this paper we may say that the requirements of an articulating telephone are that at any moment the working margin of current strength shall be directly proportional to the loudness of the sound (physically considered) and independent of its pitch. To convey a more concrete conception of

this, we may draw a curve (Fig. 1), whose ordinates will represent intensities of sound, while the abscissæ will represent periods of time. Any such curve, if it be harmonic in its character, may represent a musical sound. Now the requirement of a speaking telephone is that this same curve should represent the varying current strengths if the ordinates be currents while the abscissæ are times, as before.

These conditions are fulfilled by several different instruments to a greater or less degree of approximation. The various telephones yet devised may be classified as follows:

Class I. Telephones by induced currents (produced by the relative motion of a conductor and magnet).

(*a*). Those in which the magnet moves relatively to the conductor.

(*b*). Those in which the conductor moves relatively to the magnet.

(*c*). Those in which both move simultaneously.

Class II. Telephones by *variation* in a Voltaic current. A variation, according to Ohm's law $\left(I = \frac{E}{R}\right)$, can only be produced by varying E or R. Hence of this class there are:

(*a*). Those that vary the electromotive force.

(*b*). Those that vary the resistance of the circuit.

Class III. The Electrostatic telephone of the writer, to be directly described.

The equation of the motion of a particle engaged in the production of any simple tone,[1] is

$$y = a \sin\left(\frac{2\pi t}{\tau} + \alpha\right), \qquad \qquad (1)$$

where a and τ are the amplitude and period of the vibration respectively, and α is a constant depending on the time that has elapsed from the commencement of the motion until the moment we begin to reckon. The variable velocity of the particle is

$$\frac{dy}{dt} = a. \cos\left(\frac{2\pi t}{\tau} + \alpha\right)\frac{2\pi}{\tau}. \qquad \qquad (2)$$

For our purpose a sufficiently exact expression for the kinetic energy of the vibrating particle while producing any note can be reached

[1] Donkin, "Acoustics," p. 47.

as follows: The total energy of the vibration at any time consists of two parts, kinetic and potential, the sum of which is constant. The whole of it will be manifested as kinetic energy as the particle passes its point of equilibrium. At this point $y = 0$, hence

$$\sin\left(\frac{2\pi t}{\tau} + \alpha\right) = 0,$$

$$\therefore \cos\left(\frac{2\pi t}{\tau} + \alpha\right) = \pm 1,$$

$$\text{and } \frac{dy}{dt} = \pm \frac{2\pi}{\tau} a.$$

But the kinetic energy is $\frac{1}{2} m v^2$

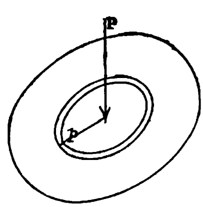
$$\therefore \tfrac{1}{2} m v^2 = 2 m \frac{\pi^2 a^2}{\tau^2}. \qquad (3)$$

Then the whole force exerted by any collection of particles vibrating synchronously will be

$$\Sigma \frac{m v^2}{2} = \Sigma \frac{2 m \pi^2 a^2}{\tau^2}.$$

From which we see that with a given mass of vibrating particles the kinetic energy varies as the square of the amplitude divided by the square of the period; or, what is the same thing, as the square of the product of the amplitude by the number of vibrations in a unit of time.

Fig. 2.



In all telephones yet devised, the aerial undulations are received on a flat disc of thin elastic substance—such as mica, rubber, or iron—and hence this portion of the theory is common to all forms. The complete investigation of the relations between the applied forces and the resultant action of the plate in the telephone forms one of the most complex dynamical problems in the whole range of science, but an expression for the relation between the variables, sufficiently exact for our purpose, may be reached in the following manner. Let us treat the problem as one of shearing stress, Fig. 2:

Let $P =$ applied force,
$\Delta =$ deflection of plate,
$\rho =$ variable radius,
$t =$ thickness of plate,
$e =$ coefficient of transverse elasticity.

Then[i] according to the law of shearing stress,

$$P = 2\pi t e \rho \cdot \frac{d\Delta}{d\rho}; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

whence we have

$$d\Delta = \frac{P}{2\pi t e} \cdot \frac{d\rho}{\rho};$$

and integrating between the limits r, the radius of the plate, and r_1, the radius of the area on which the force is applied, we have

$$\Delta = \frac{P}{2\pi t e} \cdot \log \frac{r}{r_1}. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (5)$$

From equations (3) and (5) we see that within the elastic limit of the plate, the deflection will be proportional to the kinetic energy of the sound wave.

"It can be shown that no forced vibration can have any harmonic component of a period which does not exist amongst the periods of the harmonic component of the imposed motions or forces."[ii] The plate then must follow every motion of the alternately condensed and rarefied air particles. Though I have only given an expression in equation (3) for the kinetic energy of a single note, it will readily be perceived that in the case of a complex motion, at any given moment, the energy will be represented by that expression. The discussion of the general equation would be too lengthy for insertion here, but can easily be found by those interested. (See Donkin's "Acoustics" and Rayleigh's "Theory of Sound.")

The theory of the three divisions which I have made in the first class of telephones, is the same; hence an exposition of the theory of the Bell Telephone will answer for the other two. By the Bell Telephone we will understand that arrangement of a vibrating plate of magnetic matter before the pole or poles of a magnet—temporary or permanent—around which pole or poles wire is wound after the manner of an electro-magnet. In a general way the explanation of its action could be given somewhat in this wise: The motion of the plate, by disturbing the distribution of the magnetic field, causes a motion of the magnetic lines of force, which, cutting across the wires of the helix, cause a current to be induced in these wires. This current, passing over the line, causes a variation in the force with which the

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[i] Wood, "Resistance of Materials," p. 215.

[ii] Donkin, "Acoustics," p. 89.

plate at the further end is attracted, and the variation imparts to the plate a motion depending on the varying strengths of the incoming current. The motion of the lines of force can be readily observed if we cover the poles of a rather powerful horse-shoe magnet with not too fine iron filings, and move the armature to and fro before the poles. It can also be readily shown by means of the floating magnetic needles described by Prof. A. M. Mayer, in the *Am. Jour. Sci. and Arts*, for April, 1878.

The theory of the action is as follows:[1]

If m be the magnet strength, and the induced magnetism of the plate, which, of course, is a function of m, be $q\,m$, where q is some constant, then the attractive force between them will be

$$\frac{q\,m\,.\,m}{p^2}=\frac{q\,m^2}{p^2},$$

where p is the distance between the poles of the magnet and plate. Now if the plate be moved to any new position, p_2, from its initial position, p_1, work will be done by or against the attractive force.

This work $$=q\,m^2\int_{p_2}^{p_1}\frac{d\,p}{p^2}=q\left(\frac{m^2}{p_2}-\frac{m^2}{p_1}\right);$$

but $\frac{q\,m^2}{p_1}$, $\frac{q\,m^2}{p_2}$, are the values for the potential at the positions p_1, p_2, respectively; hence

$$\text{Work}=q\,(V_2-V_1);$$

or the work done will be manifested by a variation in the potential.

The potential at the time will evidently depend on the state of the magnetic field.

$$V=f(\gamma)=M\gamma.$$

But on the difference of potential at any two instants will depend the electromotive force of our induced current:

$$V_2-V_1=M_2\gamma_2-M_1\gamma_1=E=IR,$$

hence $$I=\frac{V_2-V_1}{R}=\frac{M_2\gamma_2-M_1\gamma_1}{R}, \quad . \quad . \quad . \quad (6)$$

or, the strength of the induced current will be equal to the difference

[1] For a more complete discussion see Cumming, "Theory of Electricity," p. 210; Maxwell, "Electricity and Magnetism," Vol. II, p. 176.

in the potential of the system at two given instants, divided by the resistance of the circuit. The quantity $M\gamma$ can be interpreted as the number of lines of force passing through the coil, M depending for its value on the position of the coil and plate with reference to the magnet, and γ being the number of lines of force in unit area of the equipotential surface at unit's distance from the pole at the instant that the quantity $M\gamma$ is observed. It will readily be seen that γ depends on the magnetic strength, while M depends on the arrangement and adjustment of the instrument as well as the intensity of the sound wave impinging on the plate. With any given arrangement of magnet, coil and plate, any change in $M\gamma$ will be dependent on the position of the plate, that being the only movable portion of the instrument. Hence if A be the position of the plate at any instant

$$M\gamma = f(A) = kA$$

and $$M_2\gamma_2 - M_1\gamma_1 = k(A_2 - A_1), \quad \ldots \quad (7)$$

or, the variation in the potential is proportional to the amplitude of vibration, hence the strength of the induced current will be proportional to the amplitude of vibration, and therefore proportional to the kinetic energy of the sound wave.

This current traversing the wire will cause a variation in the magnetic strength of the distant telephone, either by augmenting or diminishing it according to the direction of the current. The variation will be sensibly proportional to the strength of current, as will be shown later. Hence a force will be exerted on the distant plate proportional to the kinetic energy of the initial wave of sound. The intensity of the emitted sound will therefore, at any instant, be in direct proportion to the initial sound. It will be observed that in the above discussion no notice is taken of the pitch of the note, whatever it might be, except where it enters the expression for the kinetic energy of the initial sound wave; but it will readily be seen that whatever be the motion, if the distant plate is at every moment attracted with a force varying as the motion of the first plate, all the conditions for the transmission of sounds, however complex, are fulfilled. It remains for us to examine what are the requirements in the receiver that its plate may have a force exerted on it directly as the strength of the incoming currents.

Let m be the magnetism of the magnet, which, if produced by a current, will be directly proportional to it, $= a\gamma$.

Let K = induced magnetism of the plate $= f(m) = q\,(m)$.

Assume the initial distance of the centre of magnetism of the plate from that of the magnet $= p$. Then the attractive force $F = \frac{q\,m\,.\,m}{p^2} = \frac{q\,m^2}{p^2} = \frac{q\,a^2\,\gamma^2}{p^2}$; or the attraction is as the square of the current, as was demonstrated by Joule.

Suppose m to undergo any variation $\overline{\Delta\gamma}$, due to a variation in γ,

then $$F_1 = \frac{q\,a^2}{p^2}\,(\gamma + \overline{\Delta\gamma})^2 = \frac{q\,a^2}{p^2}\,(\gamma^2 + 2\,\gamma\,\overline{\Delta\gamma} + \overline{\Delta\gamma}^2).$$

hence, $$\overline{\Delta F} = \frac{q\,a^2}{p^2}\,(2\,\gamma\,\overline{\Delta\gamma} + \overline{\Delta\gamma}^2).$$

If $\overline{\Delta\gamma}$ be very small, $\overline{\Delta\gamma}^2$ can be neglected without appreciable error, in which case

$$\overline{\Delta F} = \frac{2\,\gamma\,q\,a^2}{p^2}\,\overline{\Delta\gamma}. \qquad \ldots \qquad (8)$$

From which we conclude that while the total strength is proportional to γ^2, the variation, if small, is proportional to $\Delta\gamma$; or, in other words, if the magnet is entirely magnetized and demagnetized by the incoming currents, the attractive force will be proportional to the square of the current; while if it be a permanent magnet, whose strength is varied, it will be proportional to the current. But if $\Delta\gamma$ be large, so that $\overline{\Delta\gamma}^2$ will have an appreciable value, the force will be augmented by the term $\overline{\Delta\gamma}^2$. Now in an articulating telephone, in order that the relative loudness of the component tones of a sound be preserved, the attractive force must vary as the current. Hence, for the receiver of an articulating telephone, a permanent magnet must be used; and, in order that $\Delta\gamma$ shall be sufficiently small, the permanent magnet should be as near saturation as possible. Hence loudness, arising from large margin of attractive force, will be fatal to perfection of articulation. In the Bell telephone, these requirements are beautifully fulfilled by the use of the same instrument as sender and receiver. This result also explains to us the imperfect working of the original form of Bell's instrument—with the electro-magnet. The magnet was too far from saturation by the constant current; hence the attractions more readily followed the law of Joule, than that of simple proportion, and the articulation was correspondingly imperfect.

The second class of articulating telephones consists of those which operate by a variation in the strength of a voltaic current. The strength of a current is, by Ohm's law,

$$I = \frac{E}{R};$$

hence, any variation in I must be caused by a variation in either E or R. We know of no method by which the electromotive force of a battery can be varied continuously; and since a discontinuous variation could hardly be made so gradual as to produce waves in the current capable of carrying the more delicate shades of quality, we are forced, for the present, to regard that telephone which varies the electromotive force to be possible only in theory. The Voltaic telephones, then, reduce to one class—those which vary the resistance of the circuit. A type of this form is what has been called the "Hydro-electric Telephone," described by Prof. Bell, in his paper read before the American Academy of Arts and Sciences, in May, 1876. This consists of a membrane, to which is attached a platinum wire dipping into water or other highly resisting liquid. The motion of the plate to and fro causes the wire to be more or less submerged in the liquid, and hence the resistance, between it and a wire projecting upward from the bottom of the containing vessel, is varied. If v be the resistance of the liquid between the extremities of the wires, R the external resistance, and E the electromotive force in circuit, then

$$I = \frac{E}{R + v}.$$

Let the plate vibrate so that the extreme values of the resistances of the liquid are v_1 and v_2, then

$$\varDelta I = \frac{E}{R + v_1} - \frac{E}{R + v_2} = \frac{E\,(v_2 - v_1)}{R^2 + R\,(v_1 + v_2) + v_1 v_2}.$$

Now if R is small, compared with v, we may, to reach an approximate solution, neglect R; then

$$\varDelta I = E\left(\frac{1}{v_1} - \frac{1}{v_2}\right) \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (9)$$

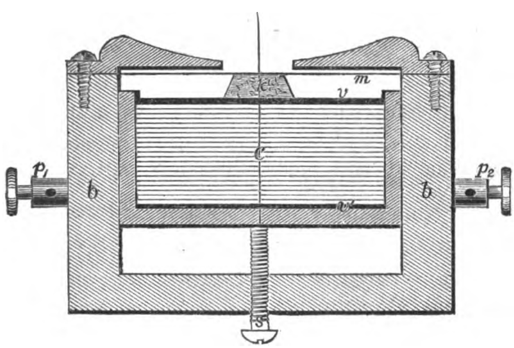
or the variation in current strength, for that amplitude of vibration will be proportional to the variation in conductivity of the circuit. To reach this result we have been forced to consider $R = O$. But this can never be the case in a practicable arrangement; but the smaller is the internal resistance of the battery and conducting wires,

and the larger the value of v_1, the nearer will the instrument approach to theoretical exactness.

In the form of instrument devised by Mr. T. A. Edison, where advantage is taken of his discovery of the variation, in resistance, of graphite or lampblack under pressure, the current is passed through the primary of an induction coil, while the secondary goes to line, and the current induced by variation in strength of the primary is utilized for actual transmission to line. If the resistance of the plumbago varies inversely as the pressure, then this instrument has the same difficulty to contend with as the "Hydro-Electric Telephone," and in the same degree.

The third class is represented, at present, so far as I know, by one instrument, the "Electrostatic Telephone," of the writer, Fig. 3.

FIG. 3.



This consists simply of an insulating box of wood or rubber, *b*, in which is placed a small condenser, *c*, the sides of which are connected by binding posts, p_1, p_2. This condenser is constructed of tinfoil, as usual, insulated by discs of thin sheet rubber, such as is used by dentists. On either end of the condenser is placed a thin piece of vulcanite, *v*, v_1, the upper one of which is attached to a piece of cork, *k*, which bears against the ferrotype or mica plate, *m*, while the lower rests on a screw, *s*, by means of which the instrument can be adjusted. One side of the condenser is kept at a nearly constant potential by means of a large number of small cells, while the other side is connected to line. The vibrating plate which bears on the condenser, by its motion, increases and diminishes the pressure, and hence the distance between the leaves. The principle of operation is as follows:

The capacity of the condenser varies inversely as the distance between the plates, and when the capacity is varied by the varying distance, of the leaves apart, a current is set up momentarily in the line, which depends for its direction on whether the condenser is under- or super-saturated for that value of its capacity. The general theory will be understood from the following. For convenience, we may consider any two contiguous sheets. Since the lines of force between the sheets cut them at right angles, the value of the force does not vary with distance, and since the electrostatic force is measured by the rate of change of potential, we have:

$$F = \frac{V_1 - V_2}{t},$$

where t is the distance between the plates. But the force near any electrified surface is $4\pi\rho$ where ρ is the density,

$$\therefore \quad \frac{V_1 - V_2}{t} = 4\pi\rho.$$

Hence,

$$\rho = \frac{V_1 - V_2}{4\pi t}.$$

If S be the area of the plate then ρS will represent the total charge.

$$\therefore \quad Q = \frac{V_1 - V_2}{4\pi t} S.$$

Hence for any variation in Q,

$$\overline{\Delta Q} = \frac{V_1 - V_2}{4\pi} S\left(\frac{1}{t_0} - \frac{1}{t_1}\right) \quad . \quad . \quad . \quad . \qquad (10)$$

or the variation in charge will be proportional to the change in *thinness* of the dielectric, since the reciprocal of the distance between the plates may be called the thinness. This thinness may, within the small limits with which we have to deal, be considered as proportional to the applied force. Then the variation in thinness will be proportional to the amplitude of vibration of the plate. Experiments made thus far with this instrument are encouraging, though its interest is more purely scientific than practical.

We have now examined the theory of a typical instrument of each class, and have found in each case, with varying degrees of approximation: (1.) That the amplitude of vibration of the plate was proportional to the kinetic energy of the sound wave. (2.) That the current on the line was proportional to the amplitude of vibration of

the plate. (3.) Assuming the attractive effect of the current as directly proportional to it, the amplitude of vibration of the receiving plate is proportional to the strength of the current. (4.) That the kinetic energy of the sound emitted by the receiving plate is proportional to the amplitude of vibration of that plate, and hence the kinetic energy of the sound emitted is directly proportional to the kinetic energy of the initial sound. No time functions enter into any of equations (6), (8), and (10). Hence the action in every case is independent of the pitch of the note.

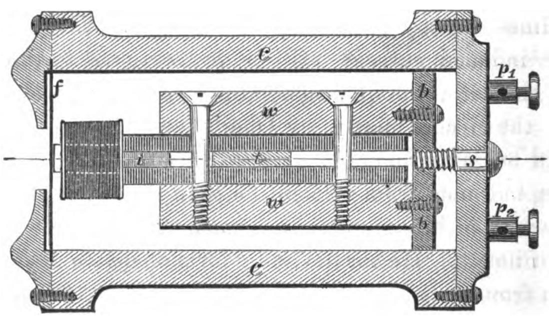
In equation (6) we see that the current depends on the change in $M\gamma$. As we have before remarked, this quantity may be considered as expressing the number of lines of force which pass through the conductor at any moment. Hence, to increase the current, the conductor should be so placed as to cut the greatest possible number of lines of force, and to allow of the greatest variation in the number of cutting lines for any given magnet strength. The electromotive force of the induced current will be proportional to the number of windings in the coil; the quantity to the electromotive force and conductivity of the circuit jointly, by Ohm's law.

The writer has experimented a great deal with the different forms of telephone, but more from a scientific than a practical point of view. Still in the course of his experiments some facts have been reached that are worthy of notice. He has devised a form of instrument differing in construction from the ordinary Bell Telephone, and having the advantage of greater ease and cheapness of manufacture. This instrument has been used by many scientific men who have visited the Stevens Institute, with the nearly unanimous opinion that it compared very favorably with the best yet constructed.

A sectional view of this instrument is shown in Fig. 4. The wooden case *c*, $4\frac{1}{2}$ inches in length by $2\frac{3}{4}$ in diameter, is, in the instrument made by the writer, of mahogany. Through this cylindrical block is bored a hole, 2 inches in diameter. Into this is fitted snugly the arrangement of magnets and coils tight enough to prevent its rattling about, but not so tight as to prevent its adjustment by means of the screw *S*. Two horseshoe magnets are used; they are 3 inches long and can be bought at any toy store at a cost of about fifteen cents apiece. A compound magnet is formed by superposing them, like pole over like, having a piece of wood *T*, $\frac{1}{8}$ inch in thickness, between them. A small piece of round iron or iron wire *I*, $\frac{3}{16}$ inch in

diameter and $1\frac{1}{4}$ inches in length, is filed flat on two opposite sides to within about $\frac{5}{8}$ inch of the end—somewhat over half. One of the pieces is placed between the superposed like poles, and the whole is held tightly together by means of two screws passing through and into two pieces of wood *w*, *w*. On the ends of *w* is screwed a strip of brass, *b*, which, by means of a screw thread in its centre, allows the whole arrangement to be moved in and out by the screw *S*. On the pieces of round iron *i*, are slipped bobbins (which I have made of postal card, boxwood, or hard rubber), whose dimensions are: length, $\frac{9}{16}$ inch, diameter, $\frac{1}{2}$ inch, and core just large enough to fit snugly on *i*. They are wound with No. 38 wire, or for short lines coarser wire can be used. Connections are made in the ordinary way to binding posts p_1, p_2, and a disc of thin ferrotype, *f*, is placed over the end,

FIG 4.



and the magnets brought as near as possible without touching when the plate vibrates. The mouthpiece is like that of any ordinary telephone. One great advantage of this form is the ease with which a strong magnet can be made, and strength of magnet is an essential in the telephone. My instruments have a resistance of about 80 ohms, and I have worked them very satisfactorily on actual wires up to 75 miles and with resistances much higher. There is considerable choice in the ferrotype plates one meets with; the best that I have found is an imported article, of a maroon color, and very thinly coated with varnish. The ordinary black American plates do very well, but the varnish is rather thick and they are not as satisfactory as the French. Of course the dimensions can be varied at pleasure, but the plate should not depart far from the size given, for if so, the fundamental tone of the plate will interfere with distinctness of articulation.

The writer has also experimented to some extent with a telephone which is a type of the second division of the first class of telephones. Two horseshoe magnets were placed about $\frac{1}{4}$ inch apart, with the opposite poles facing each other, and a circular coil of such a size as to move easily between them, and whose diameter was such that the upper portion was between the upper poles of the two magnets, while the lower was between the lower poles. This coil was attached directly to a mica membrane, and when sounds were uttered before the membrane the coil was thrown into vibration in the magnetic field, and the motion of the coil across the lines of force induced a current in the coil. Very fair results were obtained with this arrangement. This was also combined with the regular Bell telephone (Fig. 4), by attaching the coils to the ferrotype plate and allowing them to vibrate to and fro on the round iron as a piston. In this case the coil was pushed across the lines of force, at the same time that the lines of force were drawn across the coil. The articulation of this arrangement was the best that I have yet heard on any telephone, though in my experiment it was not so loud as the regular form alone, probably owing to there being a want of sufficient freedom of motion in the coils, thus damping the vibration.

In the experiments made with the electrostatic telephone, I used some 200 cells, of small test tube battery of simple zinc and copper plates in dilute sulphuric acid. The instrument had a capacity of about $\frac{1}{10}$ microfarad. While the results reached were not great enough to warrant more extensive investigation, they were sufficient to show that we had here a new means by which articulate and other complex sounds could be conveyed.

While experimenting on a wire of the Virginia Telegraph Co., the writer had occasion to notice more particularly a very curious fact which from previous experiments he had suspected before, that is, that the telephone seems to work more satisfactorily on a leaky line than on one perfectly insulated. His experiments were made on four wires. No. 1 was a wire of the Western Union Telegraph Co., from Staunton to Charlottesville, Va., a distance of 40 miles. No. 2, a wire of the same company, from Staunton to Covington, Va., a distance of 70 miles. No. 3, wire of the Virginia Telegraph Co., from Staunton to Harrisonburg, a distance of 25 miles, and No. 4, one of the Baltimore and Ohio R. R., between the same points, 25 miles. On Nos. 1, 2 and 4, which were all excellently well insulated, the

earth current was very marked, in some cases almost entirely drowning the sound of the voice, while on No. 3, a miserably insulated line, the earth current was comparatively insignificant, and conversation was carried on with the greatest ease. When this line was so nearly dead grounded, that it was nearly impossible to work with the Morse system over it, the telephone worked to a charm. The writer has sought to explain this as follows, which, be it remarked, is only provisional, for the subject deserves more attention than he has been able to give it.

It would be difficult to choose two points, at any considerable distance apart, which would be at so nearly the same potential that when they were connected by an insulated line, no current would pass. If the line were perfectly insulated the electromotive force of the earth current would be proportional to the difference of potential of the points; hence, if this difference were great the current would be great. On the other hand, if the line were leaking, this would allow of the readier equilibration of the potential at the terminus of the line and the leak, and of the difference between any two leaks, so that the earth current arriving at the distant telephone would principally be that due to the difference of potential of the nearest leak to the distant terminus and that terminus. The telephone current, of course, will lose in strength by being divided into so many branches, but being harmonic in its character, the successive currents reinforce the motion of the plate, hence a difference in the incoming current is not so readily perceived, and by adjusting, nearly as loud sounds can be obtained as if the line were insulated.

This observation agrees with the fact observed by others, that two wires could be buried in the ground and yet a telephone circuit made through them. Prof. A. M. Mayer has experimented on a railroad track, using the two rails as conductors and badly insulated and connected at switches as they were, good results were still reached. The writer has conversed with some ease between different floors of the same building, using the gas and water pipes as conductors. The same facts were observed with Mr. Edison's so-called "Etheric force;" and in fact many observations point to a close analogy between these telephonic currents and the "Etheric force," both being rapidly reversed currents. It should be noted that in the above experiments, Nos. 1 and 2 ran northeast and southwest, while Nos. 3 and 4 ran essentially northwest and southeast. No. 4, though

well insulated, was much better than 1 or 2. Such experiments give us some idea of the infinitesimal character of the currents active in this instrument, which, though escaping at every point almost, still arrive at a distance of twenty-five or fifty miles with sufficient strength to operate the telephone satisfactorily. One of the telephones used in these experiments when the plate was pressed in with the finger and held, gave, on a high resistance Thomson galvanometer, a deflection of only 1°. This points to the use of the telephone as a delicate electroscope, especially valuable where reversed currents are to be observed, as in Mr. Edison's "force," and with it very accurate measurement could be made, placing it in the cross of the "Wheatstone Bridge," or winding it differentially and balancing until no "click" was heard in the instrument at closing and breaking circuit. In fact, this is only one of the many uses to which it can be applied other than as a transmitter of speech or music, and from its wide adaptation, its beautiful simplicity, and the marvelous minuteness of the forces involved, it deserves to be classed, as it undoubtedly will be, among the greatest and most interesting inventions.

STEVENS INSTITUTE OF TECHNOLOGY,
Hoboken, N. J., March 30th, 1878.

ON THE EROSIVE AND ABRADING POWER OF WATER UPON THE SIDES AND THE BOTTOM OF RIVERS AND CANALS.

By CLEMENS HERSCHEL, Civil and Hydraulic Eng., of Boston.

[Continued from Vol. lxxv., page 338.]

Dubuat also pursued the inquiry somewhat further, and observed what became of the sand after it had started. His Sec. 72, Vol. 1, is very interesting on this point. Says he: "When the velocity on the bed of the stream is great enough to cause bodies heavier than water to roll or slide along, these bodies are not moved along with uniform velocity, but they travel, as it were, by relays. Let us take the sand for example. When the bottom of the channel is composed of sand, a little coarse and well visible, and the velocity there is 0·67 or 1·00 ft. per second, its appearance resembles that of what is known as Hun-

garian lace, forming irregular furrows at right angles to the current." Then he goes on to describe the well known wrinkles to be observed in all sandy streams, and how the sand rolls up the flat upstream slope, and rolls over the crest, down the steeper downstream slope of these furrows, to be buried up by the next grains of sand, and so on.[1] "In this way," he says, "as a mean result the same grain of sand requires two years to travel 3 miles. If the velocity increases, it goes faster, if it diminishes, it will go slower." The statement is sometimes met with, that Dubuat said that a velocity of 2 feet per second made sand travel, in the above way, about 10 miles per annum. The only authority the writer has been able to find for this is the remark of Dubuat, that in the river Hayne it took sand 2 years to go from Mons to Condé, about 20 miles apart, and the average of the 4 measurements of the Hayne velocities given in the book is about 2 ft. per second at the surface and centre of the stream, varying from 1·33 to 3·00 ft. per second. But the value of this statement may be somewhat shaken in the minds of some, when introduced, as in the original, by this remark, Sec. 400, Vol. 2: "This river does not erode sand itself, for it flows in a clay bed, ordinarily; but at Mons they are in the habit of sanding the floors, and then they sweep the sand into the streets, where it is left in little heaps; the rain washes these into the river, whence it is carried, little by little, down to Conde, requiring apparently more than 2 years to go this distance, which is about 21 miles." Dubuat must be credited, however, with having recognized that his experiments were but a beginning, and that they should not be rated too high—a piece of warning that the three subsequent generations seem to have neglected to a surprising degree. Says he, Sec. 396, Vol. 2:

"It is only by studying the course of the rivers of a kingdom, or even of all the different parts of the earth, in a thorough manner, that one could flatter himself to have gathered sufficient observations to be able to assign the proper degree of tenacity to every species of earth, and to determine the proper velocity of any stream, so that it shall neither erode its bed, nor form deposits. There is so great a variety in the combinations of the different materials which constitute

[1] For an example of the same thing on a very large scale, and in nature, see the report of Genl. G. K. Warren, U. S. Engrs., on "Fox and Wisconsin Rivers Improvement," Report of Chf. of Engrs., U. S. Army, 1876. Also separately printed; p. 73 of this edition.

the bed of a stream, that there cannot be any general rule for the determination of this velocity. Intelligent travelers would render a great service to science, if they would carefully observe the velocity at the surface of the different rivers of the earth, their mean cross-section, and the nature of the soil in which they flow. But observations of this kind cannot be made and gathered together, except in a great length of time, and it seemed proper to make at least an attempt in this direction, by the use of our experimental canal. It is with these views that we undertook the experiments now about to be described."

Robison's Mechanical Philosophy, about 1800, is often quoted from by English writers; but Dr. Robison, not having had opportunity to experiment, was obliged to confine himself to a discussion of the results found by Dubuat; and so with a host of other writers, who have repeated Dubuat's data for the movement of clay, sand, gravel, size of aniseed, peas and beans, one inch in diameter and the size of a hen's egg, in two little plank troughs, the bottom velocity being measured by the *rolling* along of some gooseberries that happened to be handy at the time, until it has become heresy to doubt any conclusions that may or may not be drawn from them. Dubuat's own words, quoted above, should teach us in which direction the path of duty lies.

The next writer in order of time, who gave the profession original data, was probably Umpfenbach, towards the end of the eighteenth or beginning of the nineteenth century. In default of the original work, the data given by him are here reproduced from an article by Prof. Sternberg, of Carlsruhe, Baden, which appeared in the *Zeitschrift für Bauwesen*, 1875, p. 495. Umpfenbach is there reported as having observed, following the hint given by Dubuat, perhaps, that when the velocity, at the surface and in the centre of "small brooks," was as given in the first column, the diameters of the pebbles, of which their bed was composed, were as in the second column.

Max. Surface velocity in "small brooks." Ft. per sec.	Diam. of pebbles. Inches.
3·1	1·0
5·2	2·0
7·1	7·0
10·0	12·5
15·0	15·5

In the same article is found this statement made by Funk, also one of the earlier German writers on practical hydraulics, who generally wrote concerning the Weser, when he spoke of rivers, that with a maximum surface velocity of 5·6 ft. per second, the bottom was composed of granite shingle 2 ins. in diameter.

Somewhere about this time, 1820 odd, originated the formula given in "Stevenson on Harbors," page 157, quoted from Sir John Leslie; $v = 4 \sqrt{a}$, "where a denotes, in feet, the side of a cubical block of stone, or diameter of a boulder, and v equals the velocity of the water in miles per hour, which is capable of moving it along the bottom." But really, if any one will refer to the original, page 392 of Prof. Leslie's "Elements of Natural Philosophy," Edinburgh, 1823, he will hardly thank Mr. Stevenson for having encumbered our harvest with this well intentioned, no doubt, but not very valuable bit of chaff among the grain. It is a formula that is evolved from purely theoretical reasoning on the impact of water, etc., and is finally modified by liberal assumptions. Taken altogether, the final conclusion left in the mind of the student, is that this formula may or may not represent the relation between velocity and size of cube, or sphere. [The formula is evolved for a cube, and it is then stated that it will be "nearly the same" for a sphere.] It will be better, not to consider it all in conjunction with the results of experiment, even when these latter have been somewhat crudely conducted.

The experiments of Dr. G. Hagen, (late "Ober-Landes-Bau-Director,") Chief of the Engineering Department of the Prussian Kingdom and its Provinces, come next, perhaps, in order of time.[1]

The works of this writer do not seem to be so well known to English and American engineers as they ought to be; but they are standard works in Germany. As an engineer of some fifty years' experience, who commenced his career under the severe schooling of the well known astronomer, Bessel, and who has made it his aim to introduce into the study of engineering principles the same careful weighing of scientific testimony that has produced such marked results in the study of astronomy, anything said by Dr. Hagen on matters of engineering, merits the close attention of the reader.

[1] See "Handbuch der Wasserbaukunst," in three parts, ten volumes in all. First two parts on water-sources, water-works, foundations, rivers and canals, in the third edition (1871–74.) Third part, works upon the sea, first edition, 1864. Berlin, Ernst & Korn.

Says he, Article 21, Part II, 3d edition: "I made the attempt to repeat them [Dubuat's experiments], using various kinds of sand, but I could not discover that there was any definite relation between the velocity and the ease with which the various sizes of sand were set in motion; at certain places where the cross-section was smaller, and hence the velocity was greater than at other places, the sand lay perfectly solid, and had been heaped up, while it had been washed away from the places last named. In large rivers, also, cases may frequently be found which confirm the experience last cited, and which show no erosion by the water, but, on the contrary, an increase of shoaling in those cross-sections wherein the mean velocity is evidently a maximum." And § 7: "In natural channels of rivers, there are many places which are notably deeper than the rest of the river, the ('pools'); one would think that these pools ought to fill up with particular rapidity on account of the decrease of velocity which they occasion, but such is not the case, and their depth remains the same, even though the pool should change its precise locality. On the other hand, there are places which have always been known as shoals and bars; they have repeatedly, and some of them have at every low water been dredged out, and yet every flood will deposit stones and sand anew in them." And in Article 8: "It is of great importance to know *in what manner it is that the water erodes the banks;* without doubt, this requires the expenditure of a certain amount of force, and this can only be generated by the motion of the water. It may be assumed, therefore, as a general proposition, that the action of the river will be greater, the greater its velocity. This is confirmed by experience, but it nevertheless remains questionable whether a *uniform* and rapid current will erode the banks; that is to say, a current in which the particles of water move parallel to the banks with a certain velocity; or whether this is not a matter less of velocity of the whole mass of water, and more of the partial and *inner movements* of the particles among themselves, and of the *whirlpools* which are known to consume a certain portion of the vis viva of the moving water. All experience tends to confirm this latter assumption; it may be doubted only in so far, that both kinds of movement of the particles among themselves, and of them altogether in line of the current, increase and decrease, the one with the other, so that it cannot be decided which of the two was the cause of the erosion that has taken place." And the subject is further discussed

philosophically and at length in Article 21. These are strange sounding words to the orthodox believer in the motion of water in straight lines or "filaments," to the devotee of "fluid veins," and of horizontal "layers" of water under all circumstances; but these notions, also, it is time were rudely shaken, especially in English literature upon the subject. It will no doubt be universally recognized before long, that it is only in the case of small and extremely regular bodies of flowing water, if at all, that these notions can be made to apply. But in natural streams such conditions rarely exist, and the artificial canals, and even pipes, that have the regularity of experimental channels, are few indeed.

These inner irregularities of motion, just spoken of, were, however, studied so early as 1791, by Venturi,[1] at Modena, whose experiments were published in Paris, in 1797, under the title "Récherches experimentales sur le principe de la communication latérale du mouvement dans les fluids."

On page 165 of the "Tracts on Hydraulics," this lateral communication of movement in fluids will be found discussed in its application to rivers, and it is more than hinted at that this is the prime cause of the erosion of the bed and the shores of rivers.

In 1848 was published a book by J. Dupuit, an eminent engineer of the "Corps des Ponts et Chaussées," and an original thinker and writer on various engineering subjects, entitled "Études Théoriques et Pratiques sur le Mouvement des Eaux Courantes," which has since appeared in a second edition. Says M. Dupuit, in the preface, page xi: "We have attempted to prove by numerous examples that these sort of questions are eminently complex; that their solution depends on a great number of local circumstances of various elements, which can neither be expressed nor combined mathematically. Mathematics is to the engineer what grammar is to the writer; it may direct ideas and inventions, but it cannot produce them. The phenomenon of the transport and the deposit of alluvial matter is explained to-day either incompletely or erroneously. We present a new theory upon this subject. We show that there are two distinct forces at work in every stream flowing upon a bed that is subject to erosion; the power of dragging along the bottom materials, which

[1] A translation of Venturi's works, in Nicholson's "Journal of Natural Philosophy," vol. iii, London, 1802. Also in "Tracts on Hydraulics," by Thomas Tredgold, 2d edition, London, 1836.

depends on the absolute velocity of the stream, and the power of suspension of the stream, which depends upon the relative velocity of the various filaments among themselves." To the elucidation of this matter, M. Dupuit has devoted the last twenty-two pages of his work, which are to be commended to the student of this branch of practical hydraulics. Says he, page 230, first edition: "If we are to be guided by a few experiments of Dubuat, according to which it would result that for a velocity of 0·30 m. (1 ft.), sand will move at the rate of 2 kilom. (1·25 miles) per annum, and for a velocity of 0·60 m. (2 ft.), it would travel only 13 (8·25 miles), we should say that this power of dragging along, which could, in course of time and by constant action, produce very appreciable effects at any one definite point of the bed, cannot produce anything but very feeble effects upon the whole length of the channel. For we are speaking now of a layer of sand exceedingly thin, and moving with a velocity which is almost inappreciable. But however that may be, there is another force residing in the water which is much more powerful against movable materials, and which has not been sufficiently considered, it seems to us. This force, which we have called the power of suspension, reveals itself in a multitude of phenomena, which leave no doubt of its existence nor of its energy.

"'Gravel is transported not only upon the bed of a stream,' says M. Minard ("Navigation des Rivieres," p. 17), 'but also is elevated and is thrown upon the shores. The dykes of the Garonne are sometimes broken during floods, and after the subsidence of the water, volumes of 6000 to 8000 cubic metres of gravel are found on the recently cultivated territories. I have seen such masses of sand, which, after having passed through breaches in the dykes on the Loire, were two or three metres higher than low water of the river.' And we could, if there were need of it, confirm what M. Minard says by similar facts observed upon the Loire; but it seems to us that they are too well known to be denied.

"Since deposits are formed upon the shores, two or three metres above low water mark, and consisting of enormous masses of gravel and of sand, it is very evident that this gravel, this sand, has been in suspension in the water; for gravel and sand dragged along the bed of the stream could not pass the breaks in the dykes and place itself in masses upon land, which is several metres higher than this bed. No other explanation is possible for this phenomenon than the

one given of the suspension of the solid matter in the water of the stream. Besides, it is easy enough to convince one's self of this property of liquids and of fluids, by excessively simple experiments; we said fluids, just now, because gases have the same property: witness the elevation by the wind of clouds of dust, and in gravelly countries carrying even gravel to a great height and producing effects entirely analogous to those that have been cited." Then after explaining how it is that a difference in the velocity of contiguous filaments or small portions of a large stream of water can move a body floating upon the surface, laterally, M. Dubuit says: "The difference in the velocity of the filaments in making unequal currents pass to the right and to the left of the floating body, engenders a power which will push it towards the filaments that flow with the greatest rapidity. This is confirmed, moreover, by daily experience: a floating body tending to detach itself from the shores and to reach the thread of the current. If we should now imagine a solid body plunged into a stream, we shall see that the relative velocity of the filaments, in a vertical, will engender a similar kind of pressure, tending to push the body towards the most rapid filaments, that is to say, acting from below upwards." And after further discussion, the results of the investigation are thus summed up: "Flowing water can hold bodies in suspension which are much more dense than it. The power of suspension depends upon the relative velocity of the filaments, and is greater, the greater this relative velocity is. Generally speaking, it varies with the quantity:

$\frac{dv}{dz} = \left[\frac{\text{diff. velocity}}{\text{diff. depth}}\right]$, so that the lower planes of the stream can carry more voluminous solids, or more of them, than those higher up."

The power of suspension of any layer is limited, that is to say, a square metre of that layer can contain only a certain number of solids of a certain size. Thus, each layer has its own different degree of saturation. It is then explained why a shallow brook will run clear at a velocity, which in a deep river might *lift up*, not roll along, sand and gravel; how it happens that rivers deposit finer and finer materials from their sources downwards; why pools are not filled up, and shallows deepened, and more of the same sort.

Mr. Thomas Login, Mem. Inst. C. E., in the *Artisan*, 1869–32, also speaks of the whirling or rotary motion of water as effecting

scour. Says he, in speaking of the way in which bridges and other works that guide water should be built, in order that they may not cause the water to undermine their foundations, the engineer "must take care that the water flows off smoothly, that is, that there be as few eddies as possible on leaving the works; but as this rolling or whirling motion cannot on all occasions be avoided, a slight increase of sectional area is necessary. Again, in nature, we never find that water flows in straight lines, but has either a whirling, or what appears to be a rotary motion, that is, any particle of water moving down a stream would follow the course of any point on the perimeter of a carriage wheel rather than that of the axes." On the other hand, in speaking of the Solani aqueduct, "a perfectly smooth, uniform channel, with perpendicular sides, and having no obstructions, either from bends or from irregularities of the bed, with a volume of water, nearly equaling 3000 cubic feet per second;" 85 feet wide, and over 900 feet long, 8·2 feet deep, and a bottom velocity of 2·60 to 3·80, averaging 3·47 feet per second. Mr. Login "found that a deposit of sand had actually taken place where the bottom velocity was three times what would be sufficient for transporting sand."

Before leaving this branch of the inquiry, the writer may offer a few reflections of his own. The traveler on the lower Mississippi floats upon a mighty river, from 2200 to 5000 feet wide, averaging about 3300 feet; from 70 to 180 feet deep, averaging about 115 feet; its velocity at the surface and in the thread of the current is about five miles per hour (about 7·5 feet per second); being a series of bends, some of them exceedingly sharp and sudden, there are produced the most violent irregularities of current; in the vicinity of a sharp curve, especially, there may be seen immense whirlpools, whose final actions and effects it would be impossible to follow to the end; but we know from observation that there are in such localities all sorts of under currents, exceeding the surface velocity, currents along shore, that run up stream at the rate of 1 or 2 miles per hour, and similar anomalies. The wonder is not that such a river should erode its banks, but how it is that clay, fine sand and mud can at all contain it. On the other hand, every engineer who has been along the seacoast will have noticed places where the tide will run on the ebb at the rate of 2 and 3 miles per hour, 3 and 4·5 feet per second, *in beds of pure sand*, and yet such channels will not become deeper, but will often fill up, on the contrary, and narrow up without any apparent cause, gradually

and slowly; they *diminish* their cross-section down to a certain limit, that is entirely unexplainable by theories of the action of the absolute velocity of the current alone, when speaking after the manner of Dubuat, as usually quoted; and reasoning from the result of experiments of this kind. But if attention be directed to the regularity of flow in such tidal streams, it will be noticed that they are generally quite shallow, running dry at low water, not infrequently, and that their flow is very regular and smooth, so that we have here a case of a very thin layer of sand moving from 5 to 10 miles in a year, according to Dubuat, that is, at the rate of about 0·0008 to 0·0017 feet per second. Whence it is explainable why such streams do not attack the bed of sand in which they flow to any appreciable extent.[1]

In an article in the "Annales des Ponts et Chaussées," 1868–1–34, on river navigation, by M. Fargue, Ingenieur des Ponts et Chaussées, and which, by the way, is unusually replete with facts and figures, the author comes to the conclusion that the shoals and pools and the scouring power of the section of river, fourteen miles long, under discussion, are regular functions of the situation and curvature of the bends of the river. His investigation seems to prove that a river will have the most regular and uniform depth of water when confined by artificial banks, whose curves consist of, and are joined to, the straight reaches by curves of the higher degree; or, if made of circular arcs, when they consist of compound curves, and whose tangents are those of what are called in mathematics osculations of the second and higher degrees instead of being simple tangents, as when

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[1] The cases here spoken of are not those of sand-bar formations, or similar cases, in which the action of the waves in throwing up sand forms an element of the problem. The impression is very clear in the writer's mind, that he has read somewhere, that in Holland, in the case of small channels leading across areas of mudflats, the depth of these channels is increased, and they are maintained in the same situation by anchoring a row of casks along their centre line. If this is true, and the writer regrets not to be able to refer to the authority, when he may be mistaken about it altogether, the explanation would be that the ebb and flood currents cause whirlpools around the casks which deepen the channel under them, and the row of anchored casks thus makes and maintains a continuous fore-and-aft channel. Since writing this much, the writer has found a form of channel producing construction, composed of a row of small piles connected by a chain, described in the "Annales du Genie Civil," 1876–96. It is there translated from the Transactions of the Holland Society of Civil Engineers, and is highly commended. After successful operation in small channels, it was about to be tried on a large scale.

a circle is drawn tangent to a straight line. He proposes to build a section of the river works, then about to be constructed upon this principle, and hopes to attain a more uniform depth of water by this means than he could otherwise expect. M. Fargue, similar to other writers which have been quoted, calls attention to the fact that "the ordinary hypothesis of the flow of water in parallel filaments, is absolutely inapplicable to the flow of rivers." And then goes on to show how the different portions of a river interchange places and penetrate each other.

ILLUMINATION BY ELECTRICITY.

By J. Jamin, de l'Académie des Sciences.

Condensed from the *Revue des Deux Mondes*, of March 15th, 1878, by Dr. William H. Greene.

The Gramme machine, as the electric source, and the Jablochkof candle have made the application of electricity to purposes of illumination, a fact beyond doubt.

The intensity of the moon's light is inferior to that of a candle, and incomparably more feeble than that of the sun.

The comparison of the electric arc to the sun, which is our highest conception of brilliancy, may be made in two ways; by the relative times required to produce equal photographic images, or by the direct measure of the illuminating powers. Fizeau and Foucault found by the first process that the power of the sun is only two and a half times superior to that of the arc; the second method has proved that the carbon points with a powerful machine are equal to the sun in lustre. It is even probable that this limit may be passed, and it is not strange, if it be remembered that our sun does not occupy the first position in the universe. It is a star already old, the cooling of which is considerably advanced and whose yellowish light begins to approach that of terrestrial flames.

In quantity and quality, the electric light greatly exceeds all flames, and in brilliancy it approaches or even surpasses the sun. It

is precisely this immense profusion of illuminating power that is urged against the electric light. It is said to be exaggerated, to exceed our requirements, that it ought to be divided, but it is indivisible.

It is true that the electric light is dangerous, like that of the sun; we may be illuminated by it, we should not look at it. But is it by any means certain that it cannot be divided or so reduced in lustre as to be rendered tolerable?

Nothing is easier than to reduce its lustre to any degree that may be desired; it is only necessary to cover the arc with a large opalescent globe. The latter hides it, receives all of the rays and dispenses them precisely as if the globe itself were luminous. It replaces the original source, at the same time increasing the dimensions, and if it be ten thousand times larger, it reduces the lustre to the ten thousandth part. It is true, this process absorbs and wastes a notable portion of the light emitted, but where the electric light can be adopted, this is of but little importance. The division of the arc can easily be accomplished by the use of the alternative currents long since devised by Le Roux, for when the alternations succeed each other at intervals of one-twenty-fifth of a second, the extinction ceases to be perceptible, and the effect is that of a continuous light. The Jablochkof candle, when the thickness and distance of the two carbons are diminished, permits a still further division, so that each candle may equal but fifty Carcel lamps, and a number of these candles may be placed in the same circuit.

The division may be carried still further, as shown by a new and remarkable experiment of M. Jablochkof's. He prepares an immense condenser composed of two tinfoil surfaces, separated by oiled silk, and folded as the condenser of a Ruhmkorff coil. The surfaces are connected with the two rheophores of an alternating current machine, so that a large space is presented on which the electricity may accumulate and condense until the direction of the current changing, each disappears to be replaced by the opposite electricity, which, in its turn, undergoes the same condensation. It is evident that these conditions should greatly modify the electric circulation in the wires, and experiment confirms the assertion. When the current is broken, brilliant sparks are produced, flashing like fire, and enveloped in a very luminous yellow flame, at the same time accompanied by

a sonorous humming sound, of the same pitch as the noise of the machine, which proves that the periodic intervals of the production of the sparks are the same as those of the formation of the currents. This experiment leads to one practical result; it is that by introducing a condenser into the circuit, the number of candles that the latter is capable of sustaining is doubled, but the light of each candle is, of course, reduced one half. All is reduced to a greater division of the illumination. It is not desirable to go beyond this point, for the Jablochkof candle, with the condenser, gives a light equal to twenty-five Carcel lamps, and, in order that electricity may be adopted as a source of light, its power must be equal to that of at least twenty Carcel lamps.

M. Jablochkof made another interesting experiment; he passed the alternating current through the interior wire of a Ruhmkorff coil, producing in the exterior wire induced currents also alternating, but of greater intensity, which are capable of diffusing upon the edge of a thin piece of kaolin, illuminating it, and maintaining the incandescence as long as may be desired. It is a beautiful physical experiment, but its practical application is doubtful.

The light of a gas flame is orange yellow when compared to that of the electric light. That a light may be applicable for purposes of illumination, it is necessary that it shall contain the seven primitive colors of the spectrum in certain proportions. All luminous bodies do not contain these colors in the same proportions. The electric arc produced between silver and carbon, contains only two green bands, and if the silver be replaced by other metals, the spectrum obtained is always formed of brilliant lines separated by wide, dark spaces. These lights are very incomplete, and would not, in any case, be used for illumination.

The spectrum of gas and oil flames are continuous; the red, orange and yellow are very abundant; there is but little green, almost no blue, and little or no violet. These flames are rich in colors but slightly refrangible, which gives them their orange tint, poor in highly refrangible rays and destitute of indigo and violet. That of which they possess too much, the red, may be removed, but it is impossible to add to them the indigo and violet which they lack, and this is the cause of their inferiority. The electric light is more complex; it proceeds at the same time from the

carbons and from the arc, and differs according to the one or the other of the sources. That from the carbons is white; it is absolutely the same as that of the sun, and contains all of the simple rays in the same proportions. It is complete and perfect and replaces daylight without any modification. It is not the same with the light from the arc itself; it is violet blue, and its spectrum tends altogether towards the most refrangible colors; it is the opposite of gas- or lamp-light; it contains little red, much blue, and a large excess of violet. It is this light of the arc which gives to electric illumination the bluish tint which has been objected to with reason. But it is a fault of excess which can be remedied, for while the missing rays cannot be added to gaslight, the superfluous rays can be removed from the electric light. The eye receives the vibrations of the ether which constitute light, just as the ear receives sounds transmitted by the air, and ceases to be conscious when the vibrations become so rapid or too slow, just as the ear ceases to hear notes too acute or too grave. But such extreme vibrations exist; there are rays below the red and beyond the violet, both of which are imperceptible to our eyes. The first are the heat rays, so abundant in the spectre of flames, the second exist in large proportion in the light of the arc, and are those which it is important to recognize and remove. Their existence may be proved in two ways, first by receiving the spectrum upon a photographically sensitive surface. The image formed in the red is very feeble, while those formed as the violet is approached become better and better; but the action does not stop at the violet. The photographic intensity is extended and increases beyond the violet, which proves the existence of ultra-violet rays of rapid vibration which our eyes cannot recognize, but which are eminently fitted for photographic action. The second method is different. If a solution of quinine sulphate be spread with a small brush upon the spectrum from the red to the violet, no effect is perceived in the red, but after the blue a whitish tint marks the path of the brush, and this is increased and becomes most brilliant in the rays which are beyond the violet. The quinine sulphate has, therefore, the property of changing the blue, violet and ultra-violet rays into white light, and, at the same time, it renders visible and useful, radiations which the eye could not perceive, and adds them to the available light.

Uranium glass and many other substances act in the same manner and present the means of suppressing the rays which are objectionable in the electric light. This suppression is necessary in other respects. These rays are said to attack the humors of the eye, and to be the origin of grave diseases.

But the electric light has its faults, one especially which will exclude it from many places. It produces a grave continuous note like the buzzing of a swarm of flies or an æolian harp. It is not a disagreeable note, but it becomes monotonous. It is produced by the succession of alternating currents lighting and extinguishing the arc at each change of direction, with a little noise each time. As this noise is produced at equal intervals, it becomes a tone, the same as that produced by the machine, and when the candles are placed in globes, the latter become resonators, and increase the sound. The Gramme machine is the only one which furnishes a silent light, because its current is continuous in the same direction.[1] The electric light, however, does not vitiate the atmosphere, and produces very little heat.

In ordinary flames, the production of light is a secondary phenomenon which accompanies the chemical combination of the combustible with the oxygen of the air. This combination is doubly objectionable, removing the oxygen from the air, and replacing it by vapor of water and carbonic acid gas. The latter, although not as dangerous as has been believed, has not a good reputation, and the best that can be said in its favor is that it does not kill. The electric light has the decided advantage of not altering the respirable medium. Chemical combination has still another inconvenience: with the light it develops such an amount of heat as sometimes to render work-rooms almost uninhabitable.

On the contrary, the electric arc does not heat. This appears astonishing at first, for all bodies fuse or volatilize when introduced into the arc; but if a very sensitive thermometer be placed in the spectrum of the electric light, it is found that there is no indication of heat in the violet rays; that in the green the thermometer begins to be heated, and that the temperature continues to rise as the red is approached, and attains a maximum in the obscure rays beyond the

[1] In the experiments made by the Committee of the Franklin Institute, it was found that all of the so called continuous current machines produced some sound in the arc.—J. B. K.

red. Now these heat-producing rays are by far the more abundant in gas and lamp flames, while the arc, which is the best test of luminous sources, emits the greatest amount of light with the least proportion of heat.

The exact cost of the electric light is yet a matter of question, but the Lontin Company furnish all of the apparatus, wires, lamps, etc., of which it retains the ownership, and demands fifty centimes an hour for a quantity of electricity, equal to 100 gas jets, on the condition of a guarantee of the use of a certain amount of light for a certain number of years. One of the proprietors of the magasins du Louvre has authorized the statement that the apparatus of the Denayrouse-Jablochkof Company, in their use, gives more light than gas with 30 per cent. less cost.

The fault has often been committed of attempting street illumination on the lighthouse system by a beam of light concentrated by reflectors, and thrown along the length of the street. Such experiments have only succeeded in blinding the by-passers and projecting behind them long shadows as black as open precipices. There are cases when such concentration is the only end that is desired. In workshops, it is only necessary that the workman shall have a clear view of the work before him. It is the same in dining-rooms, billiard-halls, reading-rooms, etc., and no one pays attention to the obscurity behind him.

It is different in depots, theatres, lecture-rooms and display store-rooms; in these cases a general illumination is required, coming from all directions, and lighting every side of an object.

When several electric lights are placed in a hall illuminated by gas, the eye immediately experiences a sort of relief, both by the redoubled brilliancy and by the perception of colors which were not before suspected; and, on the contrary, if the electric lights be suddenly extinguished, the spectators are thrown into the comparative night of the old illumination.

The conditions of good electrical lighting must be determined by a study of the general illumination of objects during the day. When the sky is clouded, the sunlight pierces the clouds as through a ground glass, and the whole sky is like an immense illuminated ceiling, radiating light from every point and in all directions. The objects illuminated diffuse in their turn the light which they receive,

so that there is an inter-crossing of rays, producing the effect of a mean amount of light everywhere; this is *general illumination.*

Such is the model that must be followed. For this purpose the ceilings, walls and floors must be well illuminated, that the diffused light may be radiated into the empty spaces; and, that the quantity may be the same everywhere, it will be necessary to multiply the sources of light. That the direct rays may not painfully affect the retina, it will also be necessary to diminish their brilliancy by the interposition of ground glass and some florescent substance, such as quinine sulphate, in order to transform the violet and ultra-violet rays into white light. Lastly, and especially, it will be necessary to cover all openings by which the light may escape.

The exterior light enters by the windows during the day, and it is by them that the nocturnal illumination escapes. M. Jablochkof introduced electric lighting into the laboratory of the Sorbonne, and the feeble effect it produced was astonishing. This laboratory is covered with a glass roof, by which it is well lighted during the day, and by which it allowed the loss of at least one-half of the light produced by the electric candles. This wasted light illuminated the high walls of the surrounding buildings, and gave a brilliant but useless illumination in the court. A similar occurrence took place last summer on the occasion of an experiment attempted in the Palais de l'Industrie. All of the light had been concentrated in six lamps, far from each other; this was the first fault which would have been avoided by distributing a large number of less powerful lamps throughout the immense building. Lastly, all of this light, instead of being directed towards the spectators by a well-combined system of diffusion, escaped through the vast glass roof, to be uselessly lost in the heavens. The experiment would have succeeded had the roof been covered with a thick white covering, destined to reflect back the light so prodigally wasted.

The same thing happens with gas, and will occur with electricity in the illumination of public places. All of the lamps waste half of their light in radiation towards the sky. A simple reflector would return it to the ground and double the illumination.

ON THE DEVELOPMENT OF THE CHEMICAL ARTS, DURING THE LAST TEN YEARS.[1]

By Dr. A. W. Hofmann.

From the *Chemical News.*

[Continued from Vol. lxxv, page 201.]

Other methods for the industrial conversion of sodium nitrate into potassium nitrate are probably no longer in use. In an early process the potash salts from the manufacture of beet-root sugar were utilized. The aqueous solution contains principally potassium sulphate, chloride, and carbonate, and sodium carbonate. On concentration to specific gravity 1·38 (40°B.) the sulphate of potash separates out whilst the liquid is hot, and the greater part of the chloride on cooling. The mother-liquor separated from these salts was mixed with Chili saltpetre and concentrated further, when carbonate of soda, mixed with more or less chloride of sodium, was deposited and fished out. The clear mother-liquid, on cooling, deposited potash saltpetre in crystals.

Another method, proposed by Landmann,[ii] was in use for some time in England, and was also employed by Nöllner[iii] at Billwerder, near Hamburg, at the time of the Crimean war. It depends on the decomposition of caustic potash and Chili saltpetre, yielding caustic soda and potash saltpetre. The latter is crystallized out, and the former evaporated down, and sold as lump caustic soda. According to an account by G. A. Scherf,[iv] the following rather circumstantial process is used in America for the simultaneous production of potash saltpetre and baryta-white, by reason of the heavy duty on salt and the high price of hydrochloric acid. Chili saltpetre is converted by chloride of barium into nitrate of barium and chloride of sodium. Stassfurt chloride of potassium is converted into sulphate of potassium and hydrochloric acid by heating with sulphuric acid, and the sul-

[1] "Berichte über die Entwickelung der Chemischen Industrie während des letzten Jahrzehends."

[ii] Landmann, *Dingler*, cxvii, 78.

[iii] Nöllner, *Polyt. Notizbl.*, 1867, 370.

[iv] Scherf, *Wagner*, 1866, 227.

phate of potassium thus obtained is finally converted by treatment with the barium nitrate into potash saltpetre and baryta-white.

We have still to mention Delafield's[i] proposal for the simultaneous manufacture of white-lead and potash saltpetre. He precipitates a boiling solution of nitrate of lead with carbonate of potash, when a carbonate of lead, agreeing in composition and properties with white-lead, is thrown down, whilst potash saltpetre remains in solution, and may be obtained by concentration.

In the technological analysis of nitrate of potash, the chlorine is generally determined volumetrically by means of silver nitrate, with chromate of potash as indicator; the sulphuric acid gravimetrically as barium sulphate; the potassium as the double platino-chloride, and the water and insoluble constituents by direct weighing. From these data the composition is calculated. A special examination must be made for sodium nitrate. This is most conveniently carried out according to the proposal of Nöllner,[ii] by moistening a portion of the sample—not too small—with a little water, evaporating the solution to dryness, moistening the saline residue again, and re-evaporating the lixivium. The whole amount of the very soluble soda saltpetre may be in this manner collected in a very small quantity of liquid, so that it may be recognized by its rhombohedral crystalline form, and especially by its characteristic optical behavior under the microscope with the polarizing apparatus. If it is desired to determine the nitric acid, this is, for technological purposes, best effected by mixing the sample intimately with sugar, graphite,[iii] or oxalic acid, and igniting after the addition of from 4 to 6 parts of common salt. The fused mass is lixiviated with water, and the carbonate formed is determined volumetrically with normal sulphuric acid, from which the nitrate is easily calculated. A number of other methods have been proposed, which in experienced hands give accurate results, but which are either too circumstantial for practical use, or without due care may easily lead to serious errors.

The application of potash saltpetre in the manufacture of gunpowder, and of the nitrates in fireworks, is known. Latterly, Chili saltpetre has been used according to the suggestion of Knowles,

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i Delafield, *Chem. News*, 1866, xiv, 178.

ii Nöllner, *Polyt. Notizbl.*, 1867, 306; *Dingler*, clxxxvi, 333; *Wagner*, 1867, 241.

iii Abel and Bloxam, *Chem. Soc. Quarterly Journal*, x, 107.

made as early as 1858,[i] by Hargreaves,[ii] Heaton,[iii] and Bessemer,[iv] for the decarbonization of cast-iron in the manufacture of steel, and, according to the opinion of Schinz,[v] and Gruner,[vi] has given satisfactory results. R. Wagner[vii] calls attention to the applicability of nitrate of soda in the metallurgy of copper and nickel, for the removal of sulphur from the concentrated ores, and of arsenic from the nickel speiss.

Nitric Acid.—In the industrial preparation of nitric acid, Chili saltpetre and common sulphuric acid are exclusively used, and none of the numerous proposals for obtaining it in any other manner have been carried out on the large scale. The respective proportions of sulphuric acid and of soda saltpetre are not alike in all manufactories, some using but little more sulphuric acid than the equivalent of the nitre, whilst others to 1 equivalent of nitre take as much as 1¾ equivalents of sulphuric acid. In the former case the residual sulphate is very sparingly mobile, and must be taken out of the retorts in lumps when cold. In the latter case the bisulphate formed reduces the melting point of the residue so far that it can be easily run off in a liquid state.

The degree of concentration of the sulphuric acid is regulated according to the strength of the nitric acid to be prepared. Ordinarily, sulphuric acid is used at specific gravity 1·718 (60° B.), as obtained by concentration in lead pans. Experience has proved that with this strength the mixture froths least, so that the retorts may be charged tolerably full. The average strength of the nitric acid thus obtained varies with the quantity of sulphuric acid used and the heat applied, but ranges in general between specific gravity 1·38 to 1·41 (40° to 42° B.). For the preparation of weaker kinds this acid is diluted with water, which is placed previously in the condensing apparatus. For stronger nitric acid a more concentrated sulphuric acid must be taken, and for nitric acid of specific gravity 1·50 to

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i Knowles, *Repert. Patent Inv.*, 1858, 239; *Dingler*, cxlix, 317; *Wagner*, 1858, 14.

ii Hargreaves, *Mech. Mag.*, 1868, 11, 30; *Dingler*, clxxxvii, 480; *Wagner*, 1868, 84.

iii Heaton, *Dingler*, clxxxvi, 489; *Wagner*, 1868, 87.

iv Bessemer, *Prakt. Mech. Journ.*, 1868, 143; *Dingler*, cxc, 32; *Wagner*, 1868, 88.

v Schinz, *Dingler*, cxcv, 126; *Wagner*, 1870, 70.

vi Gruner, *Comptes Rendus*, lxx, 521; *Wagner*, 1870, 70.

vii R. Wagner, *Wagner's Jahresber.*, 1870, 116, 151.

1·53 (48° to 50° B.), which almost corresponds to the pure monohydrate, dried Chili nitre, and oil of vitriol at specific gravity 1·85 (66° B.), must be used.

The apparatus employed consists in general of horizontal cast-iron cylinders, set so that they may be enveloped as equally as possible in the hot furnace-gases. In some works an attempt is made to protect the upper half of the cylinder from corrosion by the acid, by means of a lining of bricks or a coating of fire-clay. This arrangement is, however, useless if the iron is kept so hot that no nitric acid can be condensed upon it. The expedient may even have an injurious effect, since the porous mass of clay is less strongly heated than the metal, and easily retains a portion of nitric acid, which, when the cylinder cools, may attack the iron. The two ends of the cylinder are not exposed to the fire, and are therefore best closed with plates of sandstone luted with a mixture of iron-filings, sal-ammoniac, sulphur, and vinegar. This luting sets rapidly, and resists the action of the fire and of the acid very well. The front end slab has in its upper half an aperture which serves for the introduction of the nitre, and can be closed with a stone stopper luted with clay. In this stopper is a smaller orifice, through which, when everything else is arranged, the sulphuric acid is run in by means of a lead pipe. At the lower part of the front of the cylinder there is a concavity with a hole 8 centims. in diameter, through which the liquid sulphate of soda is removed at the end of the operation. During the process this hole is closed with a cast-iron stopper luted with clay. The back stone slab is perforated to receive a fire-clay pipe, which connects the interior of the cylinder with a series of stoneware jars which serve as condensers. The uncondensed gases are passed into a coke-tower, where they encounter a descending shower of water, which condenses the last traces of nitric acid, and with the joint action of air converts into nitric acid any hyponitric acid present. The stoneware vessels (*bombonnes*) are generally of the same form as those used for hydrochloric acid. Each has two wide apertures for the connecting pipes, and a smaller one for drawing off the acid.

Devers and Plisson[1] have modified the form of the condensing apparatus, so as two jars are placed one above the other in such a manner that the upper is fitted like a funnel into the middle aperture

[1] Schwarzenberg, "Nitric Acid," in Bolley's "Technologie," ii, 1, 2, 304. Brunswick : 1865.

of the lower. The acid as it condenses flows into the lower jar, and from there, through a syphon luted in, to a large receiver. At the end of the condensing plant there are still several jars placed upon each other, and filled with fragments of pumice, in which the hyponitric acid is condensed by a current of water. If about equal equivalents of sulphuric acid and nitre are used, the residual sulphate of soda, as has been already mentioned, is not sufficiently mobile to flow out. The front end of the cylinder is then closed with a cast-iron plate, protected within by a lining of clay. The plate is luted with a mixture of clay and horse-dung, as the iron-lute mentioned above sets too hard. Before charging the cylinder, some prismatic bars of cast-iron with sharp edges are laid at the bottom. On these the cake of sodium sulphate breaks as it cools, and can thus be easily taken out in pieces.

Instead of the cylinders many manufacturers use cast-iron troughs, whose sides are lined with sandstone plates, or with blocks of stone, and which are closed above with a sandstone slab or with a double arch. This arrangement is less advantageous, the outlay in fuel is greater, and the apparatus itself is more readily corroded by the acid.

A preferable construction is a large cast-iron boiler, with a wide aperture above for the introduction of nitre and sulphuric acid, and closed during firing with a cast-iron lid. The boiler is set so as to be exposed to the flames all around and even above the lid. The nitric acid is led to the condensers by a neck cast on to the boiler, and lined with a stoneware pipe as a protection against the action of the acid. The soda sulphate is run out through a pipe cast at the bottom of the boiler. The liquid sulphate is best received in iron boxes standing on small iron trucks, and conveyed away immediately. When cold it is broken in pieces and converted into neutral sulphate (salt cake) for the alkali manufacture by ignition with common salt.

The nitric acid as produced is always tinged more or less with yellow, owing to the presence of hyponitric acid, and contains an amount of hydrochloric acid corresponding to the proportion of chlorine in the nitre employed. It is, further, often contaminated with traces of sulphuric acid, sulphate of soda, ferric oxide, and iodine. To prepare chemically pure nitric acid, the tetrahydrated acid at specific gravity 1·42 (43° B.) is distilled in glass retorts, and the liquid which first passes over is kept separate as long as it pro-

duces a turbidity with a solution of silver nitrate. The receiver is then changed, and the acid is distilled over down to a small residue.

For many technical purposes it is requisite to have nitric acid free from chlorine, whilst the other impurities, when present in small quantity, have no prejudicial effect. Some establishments, for this purpose, wash the Chili nitre with pure water—or, better still, with a saturated solution of nitre free from chlorine—until all the common salt is removed. Others prefer to remove the chlorine after the acid is prepared, which is easily effected by heating the acid in stoneware pans in a water-bath, and simultaneously forcing a current of air through it by means of an air-pump. The escaping hyponitric acid containing chlorine is conducted into a coke-tower. In this manner the nitric acid is obtained as clear as water, and free from chlorine and hyponitric acid.

[To be continued.]

GASLIGHT ENGINEERING.[1]

Comparative Illuminating Effects of Coal Gas, Spermaceti, and Colza Oil. English (American) and French Standards of Measurement of Light.

By Robt. Briggs, C. E., of Philadelphia.

The measurement of the illuminating power of coal gas is established by law in both England and France; each nation adopting its own unit of valuè, and conditions of burning for the unit material, and for the coal gas measured by it. The English unit is a "standard" spermaceti candle, which must have the size and dimensions known commercially; in 1860, and before, as a "6's" candle, and is taken to burn at the rate of 120 grains per hour. The "standard" candle itself has now a more certain character than it had twenty or thirty years since. Custom, and necessity for a uniform basis ot test, have now fixed each detail of size, material, method of making the standard candles much more definitely than descriptions or drawings can express them, until the "standard candles" of any good

[1] From the *Gaslight Journal* of April 2d, 1878.

English maker, under exactly the same conditions of burning, are reliable to give equal light, within the errors of observation by the eye, or within 10 per cent. of probable actual error.

This standard candle, when used for establishing the value of illuminating power of coal gas of different qualities, is compared with a "standard burner." The latter, as usually taken in the country, is a "Sugg-Argand," the dimensions of which are given by English law; but the absence of precise requirements as to form, has permitted modifications which have increased the light-giving effect, one-sixth or one-seventh above what would come from a burner of the form of 1860, without departing from the specified dimensions in the least. The legal requirement demands further that the burner shall consume at the rate of five cubic feet of gas per hour, under a pressure, at the point of ignition, of 0·5 0·6 inch of water column, with a temperature of from 65° to 70° for both air and gas.

The French lawful unit for comparison and measurement of the light from coal gas is a Carcel lamp, of designated construction, which shall burn at the rate of 0·0042 kilo. (0·09250 pound) of colza oil per hour. Every precaution has been taken by the lawmakers to state all the conditions as to construction of lamp and nature of oil, etc., so as to insure uniformity of value for the standard unit; but the result is very little more positive than that from English law, based merely on a trade usage. Perhaps the light from the standard French lamp is slightly more constant in value than that from the English candle. The advantage is solely that of a doubt in its favor.

The French standard burner is a "Bengel" argand, of designated construction, and it is stipulated that it shall be compared with the standard lamp, when burning at the rate of 105 litres (or 3.7083 cubic feet) of gas per hour, under the pressure of from two to three millimetres (0·78 to 1·18 inches) of water column.

The comparison of the English standard candle with the French standard lamp gives 9·6 candle power for the lamp. The candle burning 120 grains per hour, or 0·01714 pound of spermaceti, demands for 9·6 candles, 0·13714 pounds, while the lamp burning its 0·09259 pound of oil in the same time; and it results that the light-giving power of spermaceti to colza oil, the light-giving effects in both instances being the most favorable, is as 1·000 to 1·492. The comparison of the French standard gas-burner with the English one,

in candle units, is an easy one. If 9·6 candles are to be the equivalent to 3·7083 cubic feet in light-giving power, how many candles will be equivalent to five cubic feet? Solution of this sum in the rule of three gives 12·944, or, for practical purposes, 13 candles.

It may be claimed with fairness that average coal gas, having the specific gravity of 0·426, and being generally like the gas which formed the subject of discussion in the paper which appeared in the April number of the JOURNAL OF THE FRANKLIN INSTITUTE (by the writer of this article), may be taken to have an illuminating power of 15 candles; and accepting this value, the comparison of the light-giving effects of coal gas, of spermaceti candles, and of colza oil in Carcel lamps, may be exhibited as follows:

TABLE.

Equivalent to one standard gas-burner.	Weight each.	Total weight.	Weight of material consumed to give equal light.
	wts. = lbs.	lbs.	lbs.
= 5 cu. ft. gas,	0·426 S. G. = 0·0319	= 0.1595	1·000
= 15 candles,	120 grs. = 0.01714	= 0·2671	1·634
= 15 / 9·6 — Carcel lamp 42	9·6 gms. = 0·09259 =	0·1447	0·908

ADDENDA TO PAPER "COAL GAS ENGINEERING."[1]

The table of figures of reduction of volumes to weights may be found to show the percentage of weights of the constituents, etc., as follows:

	Constituents.	Average Volumes per cent.		Specific gravity.		Sum.	Weight per cent.	Weight, lbs. in 100 cu. ft. gas @. 70°.
H	Hydrogen,	45	×	0·0692	=	3·114	7·3171	0·23340
CH_4	Marsh gas,	36	×	0·559	=	20·124	47·2861	1·50835
C_2H_4	Olefiant gas,	8	×	0·981	=	7·840	18·4407	0·58823
CO	Carbonic oxide,	6	×	0·967	=	5·802	13·6331	0·43488
CO_2	Carbonic acid,	2	×	1·524	=	3·048	7·1620	0·22846
$4N+O$	Air,	2	×	1·000	=	2·000	4·6995	0·14995
H_2O	Vapor of water,	1	×	0·622	=	0·622	1·4615	0·04662
						42·558	100·0000	3·18985

The absolute temperature of the flame of marsh gas, computed by the same method used in the cases of hydrogen, carbon and carbonic oxide in the paper, is:

$$\text{Marsh gas, } CH_4 = \tfrac{3}{4}\,C + \tfrac{1}{4}\,H = 13220^\circ + 3085^\circ = 16305^\circ.$$

[1] JOURNAL OF THE FRANKLIN INSTITUTE, for April, by Robt. Briggs, C. E.

AN IMPROVED FORM OF MARQUOI'S SCALE.

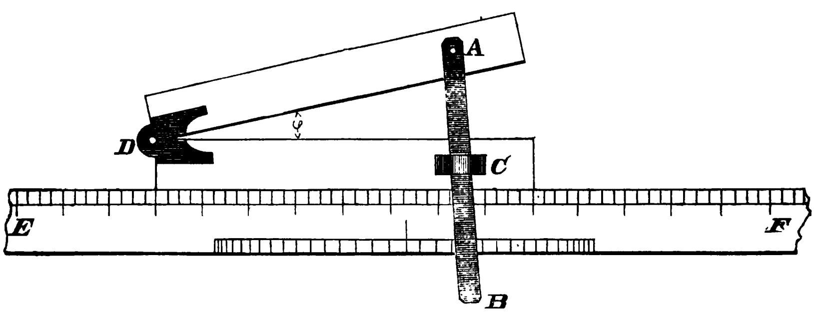
By Wm. D. Marks, Whitney Professor of Dynamical Engineering, University of Pennsylvania.

The attempt by one of the students in the Dynamical Engineering Department of the University, to invent some form of parallel ruler which would line shade cylindrical surfaces, led the writer, following out an idea suggested by Marquoi's Scales, to the invention shown in the accompanying sketch, and described below.

The instrument consists of the following parts (Fig. 1):

(1). A white wood straight edge two feet long, EF. On one edge it is divided into ¼ inch spaces. On the other edge a scale of versed-sines to a *radius* of 4 inches is laid off. Diameter, 8 inches.

Fig. 1.



(2). A pair of white wood rulers, AD and CD, each 8 inches long, hinged with an ordinary rule joint at D, and arranged so that they can be opened to any angle under 30°, and held there by means of a brass strip AB, able to turn about the pin at A, and sliding under the clamp at C with sufficient friction to be held at any point.

If we take any triangle, as GHK (Fig. 2), and laying its hypothenuse GK along a straight line GK_1, slide it along this line a distance as $GG_1 = KK_1$, we see that the new position G_1H_1 of the line

GH is distant from its former position a perpendicular distance $G_1L = GG_1$, sin HGK and parallel to it.

Let $a =$ the required distance apart of the parallel lines.

Let $m =$ the length of one division on the rule $EF = GG_1$.

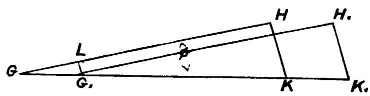
Let $\varphi =$ the angle HGK.

We have

$$a = m \sin \varphi.$$

$$\sin \varphi = \frac{a}{m}.$$

Fig. 2.



In the scale shown in Fig. 1, the upper edge of the straight edge has been divided into spaces of $\frac{1}{4}$ inch length.

To rule parallel lines $\frac{1}{8}$ of an inch apart, we must place the hinged rulers at an angle $\varphi = 30°$.

Thus,

$$\sin \varphi = \frac{\frac{1}{8}}{\frac{1}{4}} = \tfrac{1}{2}. \quad \text{Therefore, } \varphi = 30°.$$

For space $= \frac{1}{12}$ inch.	$\sin \varphi = \frac{4}{12} = \frac{1}{3}$.	Therefore	$\varphi =$	$19° 28'$
" " $\frac{1}{16}$ "	" $\varphi = \frac{1}{4}$.	"	$\varphi =$	$14° 29'$
" " $\frac{1}{20}$ "	" $\varphi = \frac{1}{5}$.	"	$\varphi =$	$11° 33'$
" " $\frac{1}{24}$ "	" $\varphi = \frac{1}{6}$.	"	$\varphi =$	$9° 36'$
" " $\frac{1}{32}$ "	" $\varphi = \frac{1}{8}$.	"	$\varphi =$	$7° 11'$
	etc., etc.			

Considering now the scale of versed sines, which is laid off along a diameter of 8 inches, for intervals of 5° of arc, and observing that the ratio of the distance between any two ruled lines to the length of a division on the rule $= \sin \varphi$; we see that we have a means of altering the diameter of the cylinder to be shaded, and also the distance apart of the shade lines in any ratio we may desire. Thus, for a cylinder 1 inch in diameter we have the ratio

	$\frac{1}{8} = \sin \varphi$	and	$\varphi = 7° 11'$
For a $\frac{3}{4}$ inch cylinder	$\frac{3}{32} = \sin \varphi$	"	$\varphi = 5° 23'$
" $\frac{1}{2}$ " "	$\frac{1}{16} = \sin \varphi$	"	$\varphi = 3° 35'$
" $\frac{1}{4}$ " "	$\frac{1}{32} = \sin \varphi$	"	$\varphi = 1° 47'$

For intermediate values φ can be accurately calculated or set by approximation, as desired.

The advantages derived from the use of this scale are:

(1). The reduction of error. Thus, an error of one one-hundredth of an inch on the scale in adjusting the rulers becomes, if the angle $\varphi = 7° 11'$, or $\sin \varphi = \frac{1}{8}$, one-eight-hundredth of an inch.

(2). An exquisite accuracy in spacing of cross-hatching, division of lines, or shading of cylindrical surfaces, otherwise only attainable by long and constant practice.

(3). The sight is greatly assisted, the divisions on the scale being so much larger than the distances between the lines.

PHILADELPHIA, *May 3d*, 1878.

THE METRIC SYSTEM.[1]

The committee, to whom was referred the communication and circular received from the Boston Society of Civil Engineers, asking the co-operation of the Club (*a*) to secure unanimity of action among the engineering professions, toward introducing the Metric System of Weights and Measures, and (*b*) to petition Congress for such legislation as may procure its universal adoption in the United States, respectfully begs to report:

That as the subject of the advantages of the several systems of weights and measures employed by different nations, has been so copiously considered during the past decade, by national and international conventions and by scientific societies throughout the world, your committee has not thought it advisable to discuss anew the merits of the several systems proposed, but have availed themselves of the existing literature and have based their report thereon.

First. They recognize in the Metric System of Weights and Measures the most desirable system of notation, either for theoretical computation or for measurements in the sciences and practical arts.

Second. They would heartily recommend the use of this system to all scientific and practical men; they advise its free introduction into all original literature bearing directly on professional work,

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[1] Report of a Committee of the Engineers' Club, of Philadelphia, adopted April 6th, 1878.

recommending the conjoint use of the English notation with it, in order to familiarize the public with its practical utility, which, if accomplished, will constitute one of the most important means for its final and universal adoption.

Third. They would also recommend its gradual introduction into machine shops, and in all practical work wherever possible.

Fourth. They would request that, in all papers read before the Club, the Metric System be used conjointly with the English, and that on all maps, sections and drawings a metric scale be placed, for comparison with the ordinary mile, foot or inch scale.

Fifth. The committee deprecates the immediate compulsory adoption of the Metric System by State or National legislation, and considers that it would be a work of supererogation to attempt to compel any class of men, either technical or practical, to adopt it to their personal or pecuniary loss.

Sixth. They recognize the compulsory education of the children in our public schools in the Metric System, as one of the most important means toward its ultimate adoption, and would recommend to the state and municipal authorities throughout the United States, the enactment of such legislation as shall make the system familiar to the working classes.

Seventh. In conclusion, your committee heartily approves of the establishment and maintenance of the permanent International Bureau of Weights and Measures (*Bureau International de Poides et Mesures*), at Paris, with the object of promoting permanence, precision and uniformity in the standards, at the proportional expense of the contracting governments, and considers it of the highest importance that such appropriations should be made by Congress as shall secure for the United States a permanent representation.

Respectfully submitted by the committee:

RUDOLPH HERING, COLEMAN SELLERS, JR.,
WM. D. MARKS, HENRY C. LEWIS,
CHAS. A. ASHBURNER, *Chairman.*

New Explosive.—Nobel has invented an explosive which is still stronger than dynamite. From its resemblance to calf's foot jelly he calls it jelly powder. It is one great defect of dynamite that when it is damp the nitro-glycerine separates from the absorbing earth. The jelly powder, which consists of 94 or 95 per cent. of nitro-glycerine, and 5 or 6 per cent. collodion cotton, is so mixed as to assume a gelatinous form, which is tough, but can be easily cut with knives or shears, and applied to cartridges or balls. It is water-proof, acts in the same way as dynamite, but is at least 50 per cent. stronger.—*Forts. der Zeit.* C.

Glass from Slag.—The manufacture of glass from furnace slag has been brought to such perfection in England that the slag is taken directly from the furnace stack, so as to avoid the expense of re-melting, and reduce the cost of manufacture to the mere wages of the blowers and pressers.—*Forts. der Zeit.* C.

Death of Monsieur Lamy.—The death of M. Lamy, Professor in the Parisian Central School of Arts and Manufactures, and former Professor in the Faculty of Sciences at Lille, is announced by *Les Mondes.* After Crookes had discovered the green spectral ray, which is characteristic of thallium, and had shown that it belonged to none of the elements which were then known, Lamy was the first who succeeded in extracting the metal and describing its most important properties. C.

Solar Radiation.—M. J. Violle recommends the employment of a series of successive measurements, in the course of the same day, for determining the calorific intensity of solar radiations, and the loss of heat which the sun's rays experience in traversing our atmosphere. In 1875 he conducted a series of experiments on the summit of Mont Blanc, according to Pouillet's method of simultaneous observations at different heights, and in 1877 he made observations at Laghouat, in Algeria, according to his new method, at an altitude of 750 metres; and at Tagrait at an altitude of 993 metres. His results show the advantage of mountain observations, and he proposes a series of observations in order to determine more exactly the action of different agents of calorific absorption in the air. He considered the Algerian stations as peculiarly favorable on account of the uniformity of meteorological conditions, the air being very dry, and containing nearly the same quantity of vapor at every hour of the day.—*Comptes Rendus.* C.

Manganese Bronze.—Prof. Genti publishes an analysis of a specimen of manganese bronze from a Transylvania factory. It is nearly of the color of brass, is tenacious and ductile under the hammer, and contains sulphur, manganese, copper, zinc, iron, with traces of silica, tin, and carbon. The essential ingredients are 15 parts of copper, 4 of manganese, and 1 of zinc.—*Revue Indust.*

C.

Black Varnish for Copper or Wood.—In a large-mouthed bottle W. M. Ayres puts 500 grammes of methylated alcohol, and 90 to 100 grammes of pulverized gum lac. In another similar bottle he dissolves 90 to 100 grammes of powdered bitumen in 500 grammes of benzine. Shaking the bottles frequently, the solution is complete at the end of two or three days. The two solutions are mixed in equal proportions, and thickened to the consistency of cream with finely pulverized charcoal. It may be rendered more fluid, if required, by adding the proper quantity of a mixture of equal parts of alcohol and benzine.—*Soc. Franc. Photog.* C.

Rheostatic Machines.—Gaston Planté describes some of the peculiar characteristics of the action of his rheostatic machine. Among other experiments he sought to transform a certain quantity of dynamic electricity, and to ascertain the time necessary to exhaust the entire charge under the form of static effects. A secondary battery of 40 couples was charged during 15 seconds by two Bunsen elements, and then put in action upon the rheostatic machine. The apparatus was turned for more than a quarter of an hour in order to exhaust this charge in the illumination of a Geissler tube.—*Les Mondes.* C.

The Telephone as a Galvanoscope.—M. d'Arsondal has compared the telephone with the animal nerve, as an indicator of electricity, and states that the poorest telephone is at least a hundred times more sensitive than the nerve. In the silence of night he has heard the telephone vibrate when the induction coil was removed to a distance fifteen times greater than that of the minimum nervous excitation, indicating, according to the law of inverse squares, a sensibility more than 200 times greater. He regards the telephone as the best of all galvanoscopes, both for feeble electric variations, and for feeble continuous currents.—*Comptes Rendus.* C.

Eddies.—In Faye's communication to the French Academy on the movement of tempests, he referred to a memoir of M. Belgrand's upon the eddies of running water. In some subsequent remarks Belgrand stated that every modification of the bed of a river produces eddies which diminish the velocity of water. The phenomenon is so common as to attract little attention. The well-determined causes, which may give some idea of the movements of the atmosphere or of the erosion of valleys, he considered under three heads: 1. Eddies which bring the water from the middle towards the banks of a water course; 2. Eddies at bends; 3. Eddies at the junction of confluents. He illustrated his remarks by references to numerous geological results, especially along the banks of the Seine, the Marne, and the Yonne.—*Comptes Rendus.* C.

Fossil Coal Flora.—The *Annales des Mines* contains a summary covering fifty pages, of Grand' Eury's works upon the determination of the age of coal beds, by the aid of fossil flora. His first memoir was presented to the Academy of Sciences, and submitted to the examination of a commission, composed of MM. Daubrée, Tulasne, and Brongniart. M. Brongniart's report, which was inserted in the *Comptes Rendus* of August 12th, 1872, recommended the insertion of the memoir in full, in the *Memoires des Savants Étrangers*, which recommendation was adopted by the academy; but M. Grand' Eury continued and enlarged his work by new discoveries, so that it did not appear until 1877. Soon after it was published it received one of the gold medals from the general union of learned societies. While adopting most of the conclusions of Ginetz, Brongniart and Gruner, his systematic botanical and geological classifications and divisions have greatly enlarged our knowledge of the French carboniferous flora, and his work is one of the most valuable contributions to vegetable palæontology which has appeared for many years. C.

The Giffard Balloon.—The captive balloon for the Universal Exposition is nearly completed. It has a capacity of 25,000 cubic metres, and a diameter of 36 metres. The bag is made of alternate sheets of calico and caoutchouc, and is supposed to be impermeable to hydrogen. It will be inflated with pure hydrogen, prepared on the spot from iron filings and sulphuric acid. It will be able to raise fifty persons to a height of more than 500 metres.—*Les Mondes.*

C.

Gas Motors for Tramways.—The Lenoir gas-engine has been improved by Otto, with a view to its employment on street railways. It is stated, as the result of several comparative trials, that the Harding steam-engine effects a saving of from 10 to 25 per cent. over horse-power; Mevarsky's compressed air-engine, a saving of from 33 to 37 per cent.; and the Otto gas-engine, a saving of from 61 to 67 per cent.—*La Gaceta Industrial.* C.

Transformation by the Simple Addition of Oxygen.—Demole has succeeded in transforming bromates of the ethylene series into bromides of the fatty series, by the simple agitation with oxygen in closed vessels. Dry oxygen and ethylene dibromate united with the liberation of heat; the product was not the oxide of ethylene dibromate, but the bromide of bromacetyle. Ethylene tribromate rapidly absorbs dry oxygen, and is changed into bromide of dibromacetyle. Berthelot compared these results to his own experiments upon the direct oxidation of free ethylene by chromic acid, with the formation of aldehyde. Propylene and camphene furnish, by the simple fixation of oxygen, propylic aldehydes and camphor.—*Comptes Rendus.* C.

Test of Woody Fibre.—Dr. Wiesner recommends phloroglucin as an extraordinarily delicate reagent for woody fibre. Place a drop of a half per cent. solution of phloroglucin upon a bit of pine, and moisten the spot with a drop of hydrochloric acid, and there immediately appears a beautiful lively red stain, verging upon violet. On drying, the violet tinge becomes still more marked. Even if the solution contains only one-hundredth of one per cent. of phloroglucin, the red color is very decided; and if there is not more than one-thousandth of one per cent., the reaction can be recognized, under proper precautions. If a strip of pine is allowed to remain in such a solution for twenty-four hours, hydrochloric acid gradually draws out a perceptibly reddish stain. The slightest traces of woody substance in vegetable tissues can be readily detected in this manner. The tenderest germs, by means of this reaction, show a woodiness in the cells. Every trace of woody substance in hemp and flax can be detected by the phloroglucin. Dr. Wiesner suggests that it may be used to distinguish hemp from flax, and also as a means of dyeing fabrics woven from vegetable fibres.—*Dingler's Polytech. Jour.* C.

Rock-Cleavage.—Daubrée has extended his studies of molecular mechanics to various features of geological structure. In the geometrical regularity which is observable in fractures produced by torsion, and slipping or shearing, he finds close analogies to the various joints, faults, schists, and minor cleavages which pervade the earth's crust.—*Comptes Rendus.* C.

Transverse Vibrations of Liquids.—M. P. Dubois has conducted some experiments upon sand, in Jamin's laboratory, substituting a liquid for sand as a means of making nodal divisions. Tinging water with vermilion, he obtains clearly marked equidistant stains, which furnish simple and satisfactory demonstrations of important acoustic laws.—*Comptes Rendus.* C.

Instantaneous Action in the Telephone.—Du Moncel attributes the vibrations of the magnetic nucleus in the telephone to the contractions and dilations of the magnetic molecules, and thinks his hypothesis is confirmed by the modifications that have been observed in the length of a bar of iron, when subjected to powerful magnetic action. The greater efficacy of induced currents in telephonic transmissions, he believes to be due to their instantaneousness, thus introducing an element like that which La Place found in the action of gravity. According to the researches of De la Rue, the currents produced by the vibrations of the voice, in ordinary telephones, represent, in intensity, those of a Daniell element, traversing a resistance of a hundred megohms, or ten million kilometres of telegraphic wire of four millimetres diameter.—*Comptes Rendus.* C.

Phosphorescence and Fluorescence.—Favé attributes both of these phenomena to "the reciprocal action of material vibrations and æthereal waves." Even ordinary phosphorus shines in a vacuum, in nitrogen, and in hydrogen, when there is no evidence of any chemical action. But when the phosphoric vapor reaches a certain density this light ceases. This furnishes one of the simplest examples of a vapor absorbing the waves which are produced by the same body when in a solid state. Such an extension of Kirchhoff's law to solid bodies is confirmed by the nitrate of uranium, which gives eight brilliant phosphorescent lines, each corresponding to an absorption line, when a spectrum is made to traverse the salt.—*Comptes Rendus.* C.

A Deep Well.—The artesian well in Pesth is one of the deepest borings of modern times. It has already reached a depth of 951 metres, while the Parisian well, at Passy, is only 547 metres deep. The water is pure as crystal, rich in calcium and baryta, having a temperature of 37° C., and flowing 6940 hectolitres per day. It is intended to sink the well until the water reaches a temperature of 65°, and flows in sufficient quantity to supply the baths and the city offices with hot water.—*Berg- u. Huett Zeit.* C.

Elastic Forces of Mixed Vapors.—DuClaux finds that aqueous solutions of monatomic alcohols obey, in their distillation, the law $\frac{\alpha}{\varepsilon} = m \frac{a}{a+e}$; a and e being the volumes of alcohol and of water in the heated liquid, α and ε the same volumes in the products of distillation. The aqueous solutions of formic and acetic acids obey, in their distillation, the law $\frac{\alpha}{\varepsilon} = m \frac{a}{c}$, in which α and a represent for the acid what they have previously represented for the alcohol. From these laws he is able to calculate the individual tensions of the vapors in the mixture, the boiling temperature in a liquid of known composition, and other important details.—*Comptes Rendus.* C.

Solar Magnetism.—Tacchini states that among the substances which correspond to the luminous rays in the solar spectrum at the base of the chromosphere, iron predominates enormously. Its vapors are the most generally diffused, and the most constant, upon the sun's surface. Next to iron comes magnesium, although its atomic weight is considerably less. Other substances are comparatively rare, and they disappear almost entirely at the epoch of minima of solar spots. He thinks that these facts may serve to explain the parallelism between the variation curves of sun spots and of terrestrial magnetism.—*Comptes Rendus.* C.

Ice-Making.—Toselli has addressed a note to the French Academy on the improvements which he has introduced into machines for making ice. He is now able to obtain blocks weighing from one to five kilogrammes, in two minutes. Pictet & Co. state that their machines produce ice at a cost of one centime per kilogramme. There are thirty-seven of their machines now in operation, some of which are employed by the English skating rinks. C.

Nettle Cloth.—At Langenschwalbach, Prussia, some interesting experiments have been made with the fibre of the common nettle. When treated in the same way as hemp, the fibres were as fine as silk and as strong as linen. The result of the first experiments was so encouraging, that a large plantation of nettles has been made, in order to test the manufacture on an extensive scale.—*Les Mondes.*

C.

Launch of the Steamship State of California.—This vessel, built for the Pacific Coast Steamship Co., of San Francisco, to run between that city and Portland, Oregon, was launched from the shipyard of Messrs. Wm. Cramp & Sons, in this city, on May 16th. So complete were the arrangements that at precisely 1 o'clock P. M., the hour named for the launch, the shoes were cut through, and she started without assistance, and slid quietly into the water without a hitch or jar of any kind.

This vessel is a full three-decked iron steamer, 320 feet long, 38 feet breadth of beam, and 28 feet depth of hold, built under the rules of the British Lloyds for the highest rating.

She will have compound surface-condensing engines, with direct-acting inverted cylinders of 51 inch stroke, the high pressure cylinder being 42 inches diameter, and the low pressure cylinder 73 inches; the engine to develop 1700 horse power. Steam will be furnished by 6 internally fired, return tubular boilers, 10 feet 3 inches long, and containing 6300 square feet of heating surface. Each boiler has 42¼ square feet of grate area.

The propeller is a true screw, 16 feet diameter and 25 feet pitch, and is expected to make 64 revolutions per minute.

She will be fitted with cabin accommodation for 200 first-class passengers, principally under the main deck, and also for 200 steerage passengers. The dining saloon, located amidships, is 40 feet long, and the full width of the vessel, and the Social Hall, of the same dimensions, is located at the upper deck, both elaborately finished in hard woods.

The State of California is to be brig rigged; will be amply supplied with boats and other life-saving apparatus for her full complement of passengers and crew; will be fitted with steam steering gear, and all the latest improvements in marine architecture, and is expected to attain a speed of 15 knots per hour on a consumption of 35 tons of coal per day.

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Book Notices.

CHEMICAL EXPERIMENTATION: Being a handbook of lecture experiments in inorganic chemistry. By Samuel P. Sadtler, A. M., Ph. D., Assistant Professor of Chemistry in the University of Pennsylvania. John P. Morton & Co., publishers, Louisville.

As remarked by the author in his preface, "the exact end and aim of the present work may be readily understood from the title, and by turning over a few pages of the book. It is a handbook, and not a text-book, in any sense whatever."

Chemical literature has long been deficient in just such a work as Prof. Sadtler has produced. Every lecturer and teacher of chemistry has felt the need of a *systematically* arranged manual to guide him in his demonstrations. Following the arrangement of the modern text-books on chemistry, the handbook of lecture experiments gives detailed descriptions of the most approved methods of demonstration. Most of the experiments are illustrated by the forms of apparatus. The cost and trouble of illustration are nowhere better paid for, than in such a work as this; this fact Prof. Sadtler has happily recognized.

The appendix on "Chemical Manipulation" contains sound and practical advice to those who are not familiar with the *tools of the trade*, and the way of using them. Tables of the metric system, and the value of the same in English weights and measures, and a comparison of Centigrade and Fahrenheit degrees, are useful and convenient addenda. A copious index, permitting any experiment to be referred to, gives additional value to the work.

Teachers, and amateurs in chemistry, will find Prof. Sadtler's handbook a help which they would be unwilling to dispense with, after once learning its value.

The publishers deserve great credit for the style in which the work has been executed; nothing better could be desired. B.

NEW ENCYCLOPEDIA OF CHEMISTRY. Lippincott & Co., Philadelphia. Parts XXVI to XXX now issued. To be completed in 40 parts, at 50 cents each.

The subject Iodine is finished in the first of the present numbers; the last takes up Oils. The great progress made in science and the arts since the work of Dr. Muspratt was laid before the public, has necessitated important changes in a work constructed on a like basis. Many details of value twenty years ago have now only a historical interest. To eliminate or condense in a work like this, requires ex-

perience and sound judgment. In the numbers before us this difficult task appears to have been performed with discretion.

The extended article on Nitro-Glycerine, and the explosive compounds into the composition of which it enters, and the applications of the same, may be remarked upon as evidencing the progress of chemical discovery since the publication of the work of Dr. Muspratt, which does not mention the subject.

The "New Encyclopedia" will fill a wide gap of twenty years with those having Dr. Muspratt's work, and who desire to bring the subject of chemistry in its application to the arts and manufactures down to the present time. B.

Franklin Institute.

HALL OF THE INSTITUTE, May 15th, 1878.

The stated meeting was called to order at 8 o'clock P. M., the Vice-President, J. E. Mitchell, in the chair.

There were present 110 members and 34 visitors.

The minutes of the last meeting were read and approved.

The Actuary presented the minutes of the Board of Managers, and reported that at the last meeting 6 persons were elected members of the Institute; and the following donations to the Library were reported:

Phonographic Instructor, by Jas. C. Booth. Philad'a, 1849.

Catalogue of Wool Manufactures, 38th Exhibition of American Institute. N. Y., 1869.

Catalogue of Paintings, Drawings, Statuary, etc., Phila: Central Fair.

Rules of 43d Exhibition of American Institute. N. Y., 1874.

Charter and By-Laws of the Franklin Institute. Phila., 1864.

Annual report of the Hartford Steam Boiler Inspection and Insurance Co. 1873.

Proceedings of the National Convention of United States' export trade, held in Washington, 1878.

Annual report of the Chief Engineer of the Water Department of the city of Phila., 1862, 1864 and 1874. From John H. Cooper.

Appendix R. R. of annual report of the Chief of Engineers for 1877, by E. H. Ruffner. Wash., 1877.

From Reading Society Natural Sciences.

Annual report of the Committee of Management of Steam Users' Asso. to the members. 1877. From the Asso.

Transactions of the Literary and Historical Society of Quebec. Sessions 1865-6 and 1867-9. Quebec. From the Society.

Forest Culture and Eucalyptus Trees, by E. Cooper. San Francisco, 1876. From H. J. Smith, Phila.

Patents and the useful Arts, by H. Howson. From the Author.

Results of the Washington Observations, 1853 to 1860, U. S. Naval Observatory. From the Observatory, through Prof. J. S. Nourse.

Fifth annual report of the New Jersey State Board of Agriculture for 1877. Trenton.

Geological Survey of New Jersey. Annual report of the State Geologist for the year 1877. From the State Board.

Publications of the Cincinnati Observatory, Nos. 2, 3 and 4. From O. Stone, Director.

Statistique international des Mines et Usines publiée par la Comité Central de Statistique de Russée et redigée, par Jean Bock. Part 1. St. Petersburg, 1877. From E. Young, U. S. Official Delegate to International Statistical Congress.

Twenty-sixth annual report of the Board of Water Commissioners to Common Council of the city of Detroit for the year 1877. Detroit, 1878. From F. D. Henry, Chief Engineer.

Die Culur-Flora der Ostrauer und Waldenburger schichten von D. Stur. Wien, 1877. From K. K. Geologischen Reichsanstalt.

Catalogue of the special loan collection of Scientific Apparatus at the South Kensington Museum, 1876. 3d Edition. London, 1877. From D. S. Holman.

Minutes of Proceedings of Institution of Civil Engineers, Vol. 51, Sess. 1877-78. Part 1. London, 1878. From the Institution.

Annual report of the Lighthouse Board to the Secretary of the Treasury for the year 1877. Wash. From the Lighthouse Board.

The Secretary reported that the Committee on Science and the Arts, at its meeting held on the 1st inst., recommended the award of the Elliott Cresson medal to Henry Bower, for having first introduced into the United States the manufacture of pure inodorous glycerine.

Mr. H. P. M. Birkinbine read the paper announced for the evening, being the second one on the Future Water-Supply of Philadelphia.[1]

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[1] Mr. Birkinbine's first paper was printed in the JOURNAL for May, and this one will appear in the July number.

Mr. Hector Orr presented a verbal communication upon silk culture in the United States.

The Secretary's Report embraced Kennedy's Spring Piston for pumps, and Applegate's Electric Door Mat Alarm.

Mr. Solomon W. Roberts presented the following preamble and resolutions, which on motion were unanimously adopted:

In Memory of Joseph Henry.

Whereas, The Franklin Institute, of the State of Pennsylvania, for the promotion of the mechanic arts, desires to express and to record upon its minutes, its deep sense of the great loss caused by the death of Professor Joseph Henry, the Secretary of the Smithsonian Institution, who died at Washington on Monday last, May 13th, 1875, in the 81st year of his age,

Resolved, 1. That in the long list of names of men eminent for their talents, their acquirements, and their usefulness, who have taken an active part in promoting the objects of the Franklin Institute, since it was established more than fifty years ago, no name shines with a brighter lustre than that of Joseph Henry.

2. That his valuable services as a member of the Committee on Science and the Arts, and his contributions to the Journal of the Institute, attest the lively interest which he took in the welfare of this institution.

3. That his career as an apprentice boy; the teacher of a school; the professor in a college; the discoverer of new truths, and the inventor of new improvements in the sciences of electricity and magnetism, and their applications to the uses of mankind, in the electric telegraph and otherwise;—as well as his services in the Smithsonian Institution; and as the founder of the Signal Service system, and the great improver of the lighthouses on the coast; will cause his name to be remembered and classed with that of Benjamin Franklin, after whom this Institute is named.

4. That the name of Joseph Henry is worthy to be honored, not only for his abilities, but also for his character; for his industry; his probity; his economical habits; his eminent trustworthiness; and his kind-hearted urbanity; and the Franklin Institute desires to unite with the scientific societies, not only of this country, but also of the world, in deploring his loss and in honoring his memory.

On motion, the meeting adjourned.

J. B. Knight, *Secretary*.

THE BOYDEN PREMIUM.

URIAH A. BOYDEN, ESQ., of Boston, Mass., has deposited with the Franklin Institute the sum of one thousand dollars, to be awarded as a premium to

"Any resident of North America who shall determine by experiment whether all rays of light, and other physical rays, are or are not transmitted with the same velocity."

The following conditions have been established for the award of this premium:

1. Any resident of North America, or of the West India Islands, may be a competitor for the premium; the southern boundary of Mexico being considered as the southern limit of North America.

2. Each competitor must transmit to the Secretary of the Franklin Institute a memoir, describing in detail the apparatus, the mode of experimenting, and the results; and all memoirs received by him before the first day of January one thousand eight hundred and seventy-eight, will, as soon as possible after this date, be transmitted to the Committee of Judges.

3. The Board of Managers of the Franklin Institute shall, before the first day of January, one thousand eight hundred and seventy-nine select three citizens of the United States, of competent scientific ability, to whom the memoir shall be referred; and the said Judges shall examine the memoirs and report to the Franklin Institute whether, in their opinion, and, if so, which of their memoirs is worthy of the premium. And, on their report, the Franklin Institute shall decide whether the premium shall be awarded as recommended by the Judges.

4. Every memoir shall be anonymous, but shall contain some motto or sign by which it can be recognized and designated, and shall be accompanied by a sealed envelope, endorsed on the outside with same motto or sign, and containing the name and address of the author of the memoir. It shall be the duty of the Secretary of the Franklin Institute to keep these envelopes securely and unopened until the Judges shall have finished their examination; when, should the Judges be of opinion that any one of the memoirs is worthy of the premium, the corresponding envelope shall be opened, and the name of the author communicated to the Institute.

5. Should the Judges think proper, they may require the experiments described in any of the memoirs to be repeated in their presence.

6. The memoirs presented for the premium shall become the property of the Franklin Institute, and shall be published as it may direct.